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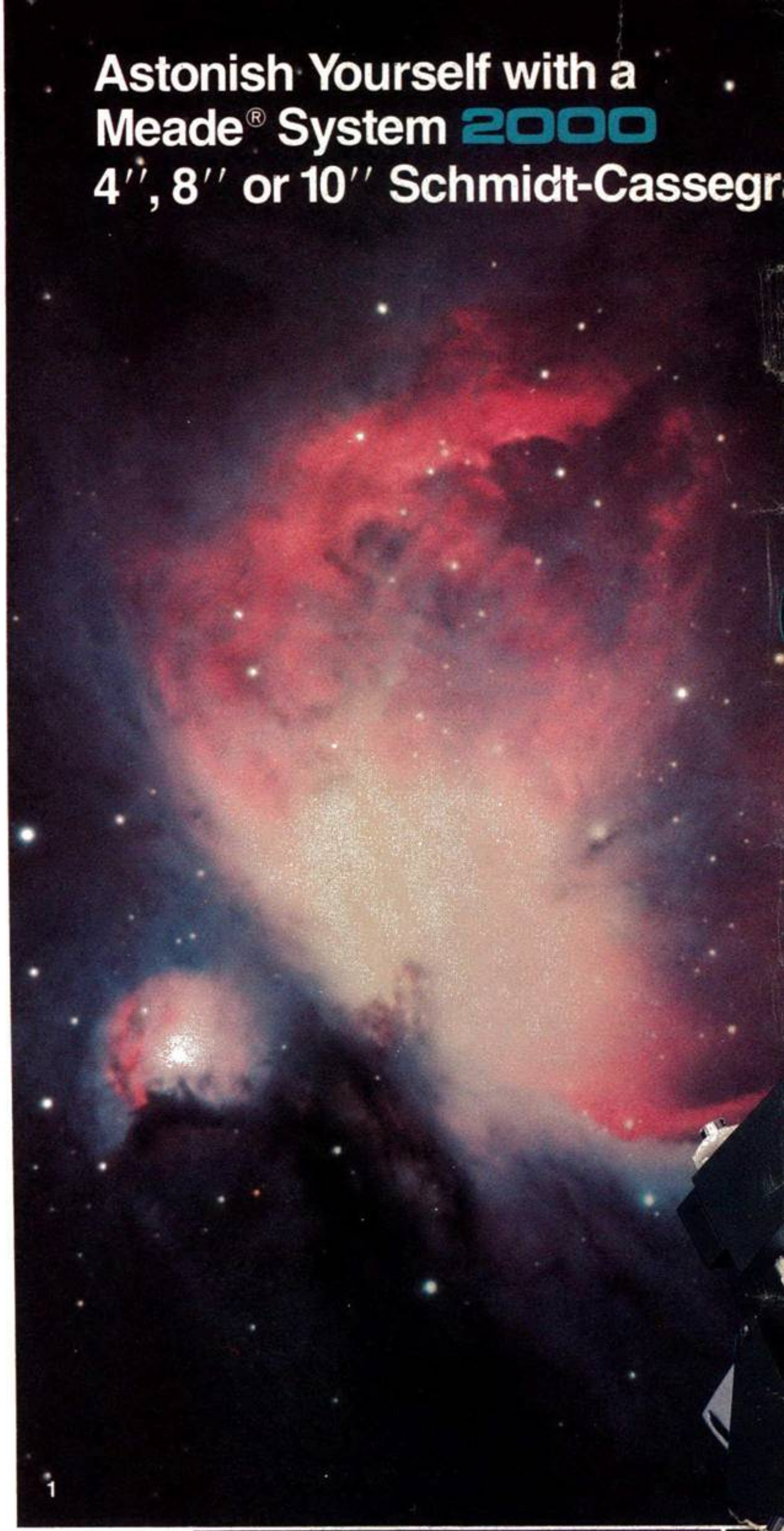
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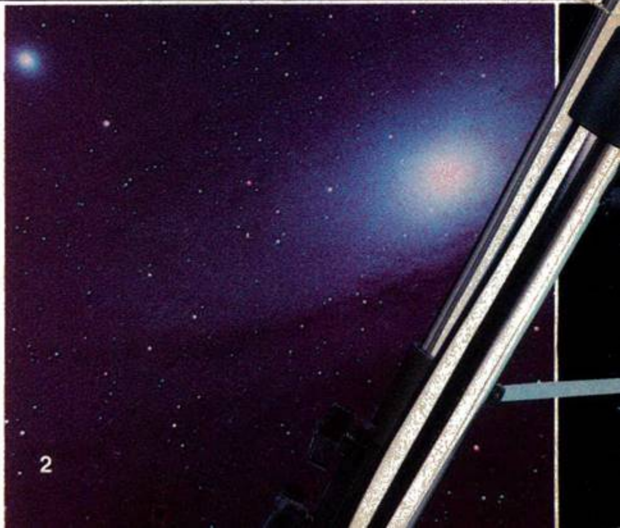
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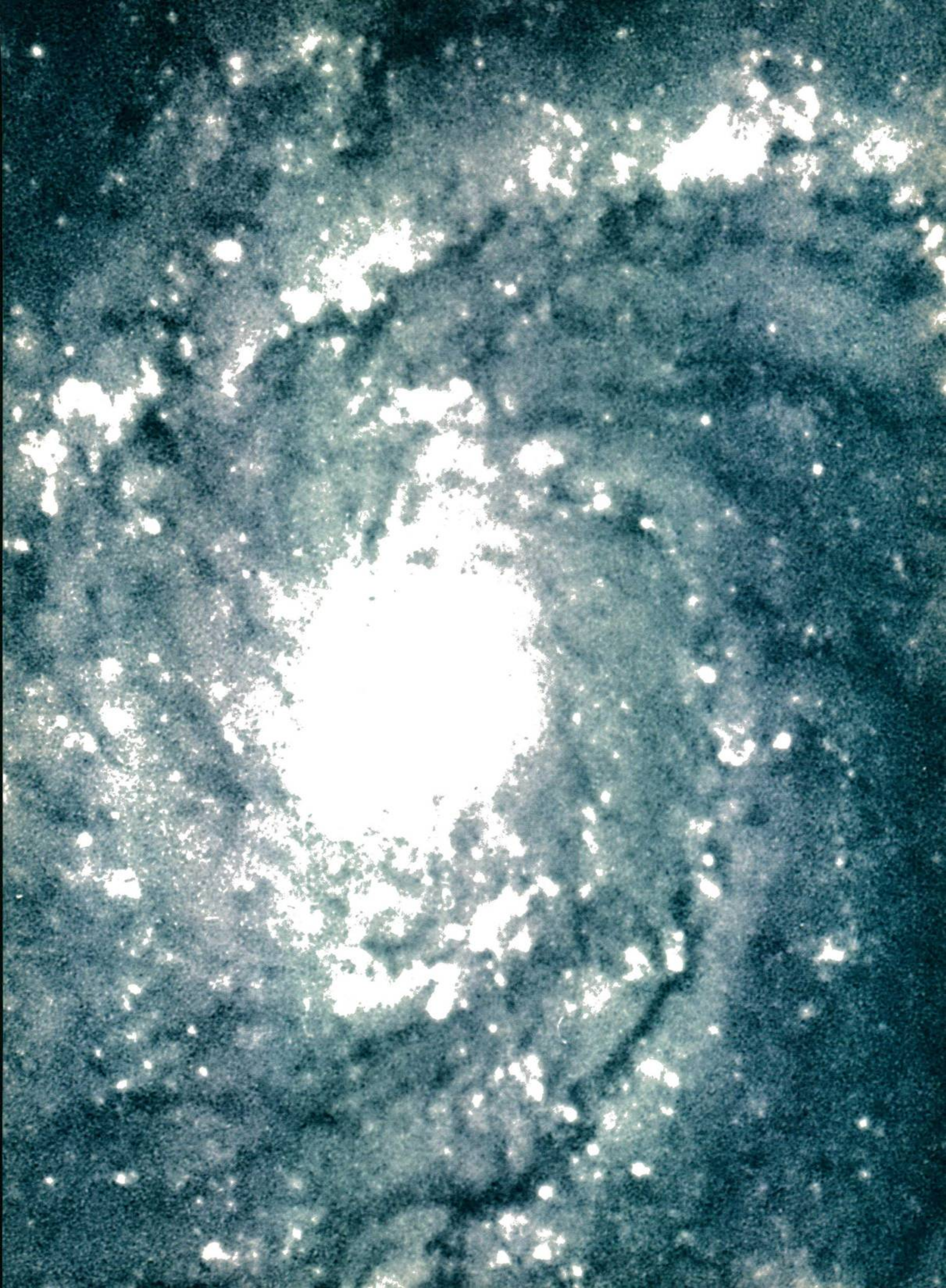
All astrophotographs shown on these pages were taken through off-the-shelf, unmodified Meade 8″ Model 2080 Schmidt-Cassegrain telescopes. For further technical details on these and many other astronomical photographs, send for your free copy of the Meade Schmidt-Cassegrain Astrophoto Brochure. (Alternately, the complete Meade 52-page General Catalog is available at $3.00 by First Class Mail and includes the Astrophoto Brochure at no additional charge.)

Key to Photographs
1, 2, 3, 5—Leo Henzl; **4, 7**—Emery Hildebrand; **6**—Paul Roques; **8**—John Sanford

1. Orion Nebula M42; exposure time 50 mins. **2.** Andromeda Galaxy M31; 60 mins. **3.** Galaxy M82; 60 mins. **4.** Milky Way in Sagittarius (50mm piggyback photo). **5.** Spiral Galaxy M33; 75 mins. **6.** Spiral Galaxy M51; 90 mins. **7.** Omega Nebula M17; 40 mins. **8.** Moon—Clavius region.



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Cover: The graceful curves of a spiral galaxy embody a challenging astrophysical puzzle. How do these massive aggregates of gas, dust, and stars maintain their beautiful patterns? What forces are at work to disrupt them? And how did their evolution differ from that of the more prosaic elliptical galaxies? As it examines the latest answers to this decades-old riddle, this month's lead article takes you deep into a world where theory and observation combine — and the best solution may turn out to be the simplest! Cover photo by James Wray, McDonald Observatory; these pages, Hale Observatories.

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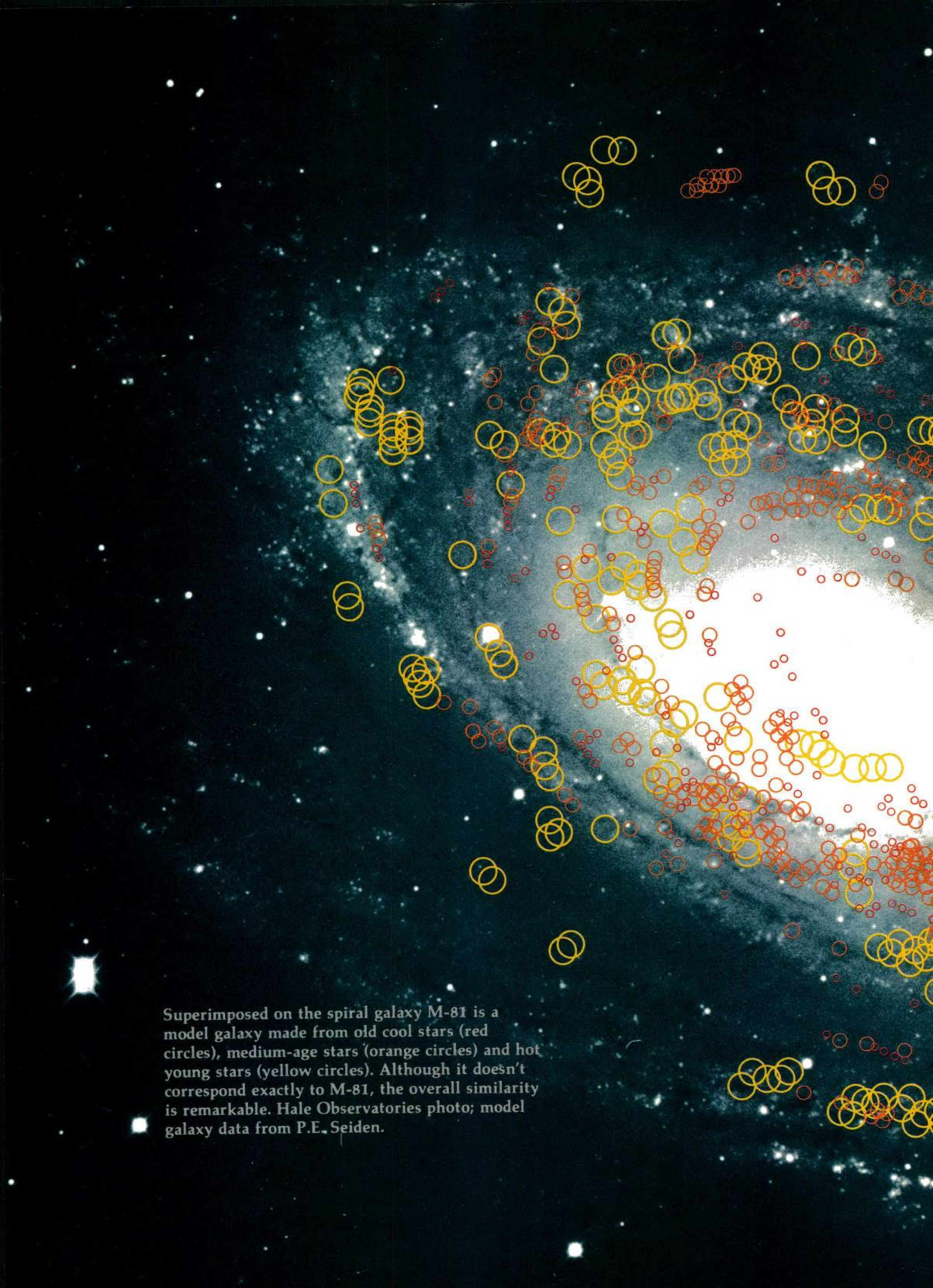
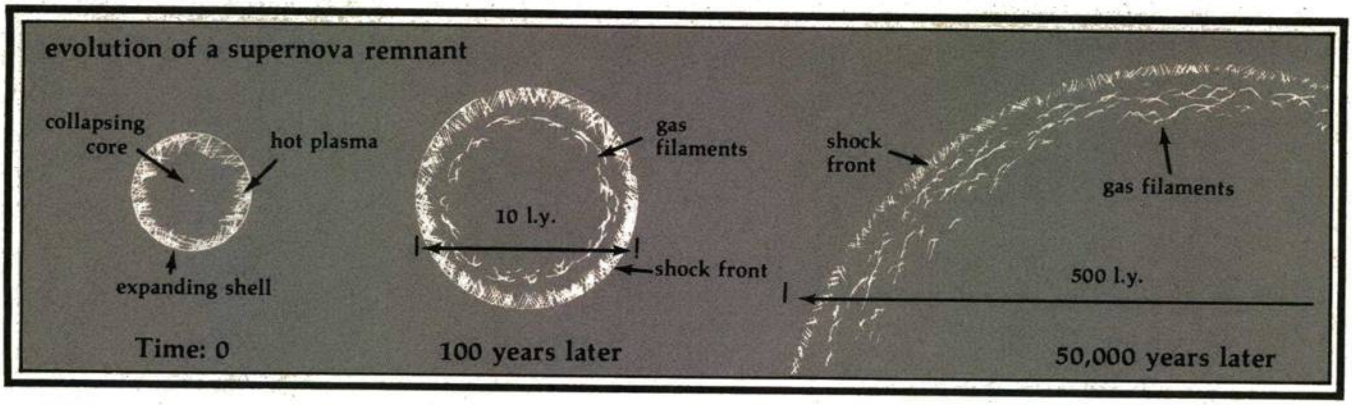


Superimposed on the spiral galaxy M-81 is a model galaxy made from old cool stars (red circles), medium-age stars (orange circles) and hot young stars (yellow circles). Although it doesn't correspond exactly to M-81, the overall similarity is remarkable. Hale Observatories photo; model galaxy data from P.E. Seiden.

To Sculpt the Galaxies

by Francis Reddy



Galaxies are relative newcomers to astronomy. A scant human lifetime ago, these huge systems of stars and gas were visible only as whirlpool-shaped patches of haze, their true nature unknown. Were these "spiral nebulae" just nearby regions of gas and dust illuminated by the light of a few embedded stars? Or were they stellar systems like the Milky Way — whole galaxies so distant that the stellar multitudes within them appeared faint and diffuse?

In the early decades of this century, astronomers confirmed that spiral nebulae were galaxies outside the Milky Way. Soon afterward, they began the difficult task of trying to understand what they were seeing. They found that galaxies also existed in an assortment of *non*-spiral forms, which ranged from orderly spheres to irregular splashes of stars and gas. Such a wide variety of shapes — spirals, ellipticals, irregulars — doesn't "just happen": some physical processes must be working to sculpt the galaxies into the forms astronomers detect by telescope. The tantalizing prospect of discovering these forces, along with developing a comprehensive theory of galactic evolution, keeps bringing the focus of astronomic research back, again and again, to the shapes of galaxies. Theoretical assaults on the problem of galactic structure have tended to concentrate on the most complex form — the spirals — for they are probably the key.

Spiral arms, delineated by dust, ionized gas, and associations of hot blue stars, gracefully arc tens of thousands of light-years out from the center of a galaxy. Beneath the beauty and complexity of spiral structure, however, lies a nagging problem: its persistence. Spiral galaxies represent about three-quarters of all galaxies. This means that spiral arms must be relatively permanent — if they weren't, we wouldn't see so many of them. But if spiral arms are permanent fixtures, and carry the same material around a galaxy through many rotations, then they should break up quickly. The reason lies in the way they rotate.

Spiral galaxies rotate differentially, that is, matter nearest the center moves at a higher angular velocity than material farther out (see "Galactic Coronas," ASTRONOMY, November 1982). In the case of our Galaxy, molecular clouds near the core complete an orbit in just a few million years. In contrast, the orbital period of the solar neighborhood — two-thirds of the way to the rim — is roughly 250 million years. As the inner parts orbit faster, they are sheared off and smeared out in a time that is short compared to the lifetime of the galaxy. Imagine what would happen to an arm of gas and stars that stuck straight out from the center. By the time the outer end has made one rotation, the inner material would have wrapped itself around the core many times. Yet despite the fact that the Sun and its neighborhood have made some 20 complete rotations in the past 5 billion years, studies of molecular clouds by radio astronomers show that the Milky Way still has a distinct spiral structure. Clearly something either maintains or regenerates spiral arms. But what forces could possibly organize galactic material over thousands of light-years' distance and eons of time?

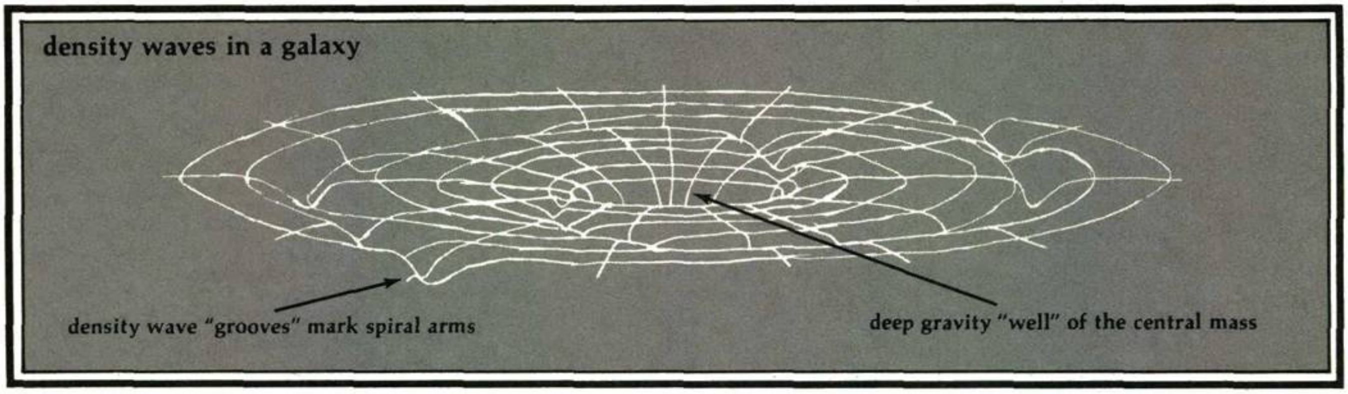
The blast wave of a supernova, propagating through the interstellar medium, will give the gas clouds of a galaxy a firm push — and perhaps trigger the formation of other stars from them. Photo by Philip Angerhofer, USNO.

About 30 years ago, the interstellar magnetic field was thought to be responsible for the regulation and maintenance of spiral arms. In 1953, Subrahayam Chandrasekhar and Enrico Fermi suggested that spiral arms are merely tubes of ionized gas held together by the galactic magnetic field. To understand how their model worked, let's look at how material behaves in a magnetic field.

Atoms that have lost one or more electrons are called ions. These electrically charged particles can move within a magnetic field only by spiraling around the magnetic lines of force. Ionized gas in a galaxy, then, might be bonded to the interstellar magnetic field, trapped within a magnetic "bottle." While magnetic entrapment requires ionized gas, which represents only a fraction of a galaxy's gas content, these electrically charged particles spiraling along magnetic field lines would create a barrier, or "spin a web," that uncharged gas and dust would find difficult to penetrate. Thus, in theory at least, a small fraction of galactic gas could contain a far larger quantity of neutral material in a spiral arm — provided the interstellar magnetic field were powerful enough.

Unfortunately for the theory, measurements made in the late 1960s indicated that the Galaxy's magnetic field is simply too feeble to bottle the interstellar medium. But there is another force capable of organizing great quantities of matter over enormous distances — gravity.

In the mid-1960s C.C. Lin and Frank Shu proposed that spiral structure is created by waves of material driven by the gravitational field of a galaxy. These waves are actually large-scale concentrations of


density waves in a galaxy
density wave "grooves" mark spiral arms
deep gravity "well" of the central mass

Above: Most astronomers think that density waves control the spiral shape of a galaxy. These waves of "extra-strength gravity" spread out like grooves from the deep central mass of a galaxy, and collect dusty gas to form bright new stars which outline the pattern of spiral arms. Right: M-101, a classic spiral galaxy. Hale Observatories photo.

gas and dust. Since the density of material within them is greater than that of the surrounding space, these concentrations are called density waves. Left to themselves, though, density waves will still die out in a relatively short time. To counter this, Lin and Shu assumed that a rotating galaxy contains a quasi-permanent spiral-shaped region of low gravitational potential.

An easy way to picture this is to imagine the groove on a record. In a gravitational field, matter prefers to lie in areas of low potential rather than areas of high potential. (In the Earth's gravitational field, for example, this means that things roll downhill as far as they can: coffee sits in the bottom of a cup, and dust settles out of the air onto all the table tops.) Material rotating around a galaxy will eventually encounter the groove. Since the groove is at a lower gravitational potential than the surrounding space, matter will tend to linger in it.

Although it affects all matter, the groove has less effect on stars, which are relatively massive and which merely hesitate briefly in the groove before they continue on their long circumgalactic journeys. Interstellar gas and dust, on the other hand, have relatively low mass and thus accumulate within the groove and become compressed. In addition to forming the spiral arms, the compression may be severe enough to trigger the formation of stars within the gas; in this case, spiral arms should contain many hot young stars, lanes of dust, and great regions of hot glowing gas — precisely what is observed. Spiral arms, according to the Lin-Shu density-wave theory, are not fixed collections of mass, but rather ephemeral increases of density that are continually created and destroyed in the galactic disk.

Of course, postulating density waves as the source of spiral arms raises the problem of where the groove itself comes from. The spiral trough necessary to regenerate the waves could be created through close encounters between galaxies. Such "near misses" would shuffle the stars in each galaxy, and a mere 10% increase in the density of stars is all that is required to drive a substantial wave through the gas.

The density-wave theory implies that spirals are created in an orderly, even stately, fashion; such spiral features should be neat and tidy. But even a quick look at a photo of a galaxy shows that a great deal of the structure in spiral galaxies is clumpy, and some of it is downright ragged. By examining only the large-scale forces in a galaxy — the big picture — are we missing something? If so, what effect could small-scale forces have on large-scale galactic structure?

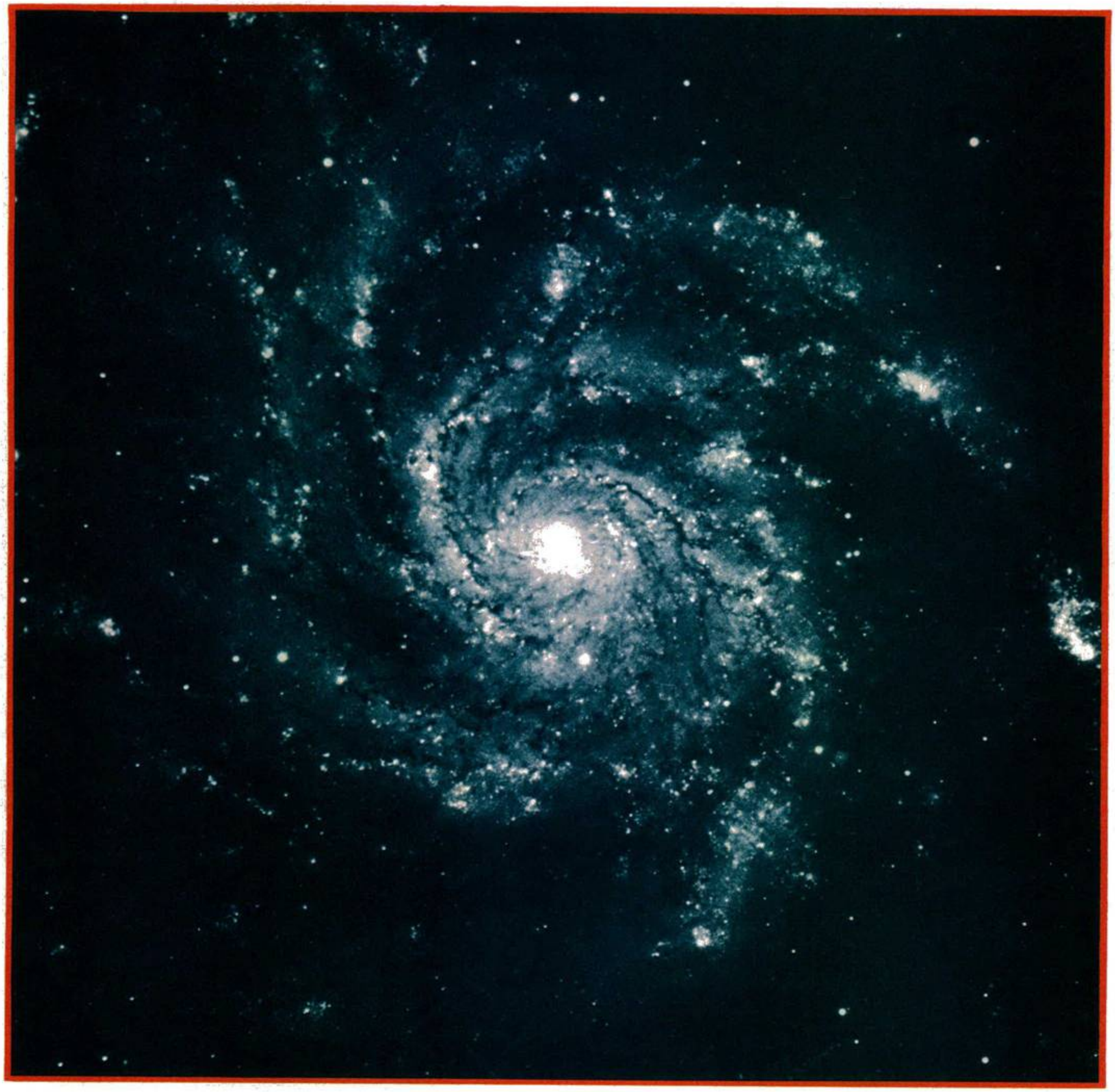
The most powerful "local" event in a galaxy is the explosion of a supernova. Shock waves from the destruction of massive stars have a dramatic effect on the interstellar medium, and it is widely believed today that supernovae can trigger the formation of stars. While the idea itself is not new, astronomers have only recently acquired a great deal of suggestive observational evidence. From the examination of both old and new supernova remnants, astronomers have pieced together the evolution of these violent events and their effect on the space around them.

Deep within a massive star, at a certain point in its lifetime, the delicate balance between thermal expansion and gravitational contraction goes awry and the star explodes. Brightening by as much as 10 billion times — perhaps outshining its parent galaxy — the star heaves much of its mass radially outward. A shell of ejected material slams into the space surrounding the star and produces a shock wave in the interstellar medium.

The temperature of the matter behind the shock front may remain extremely high for tens of thousands of years, and the expanding shell radiates energetic X-rays. As the remnant continues to expand, the temperature behind the shock front drops and its radiation shifts toward progressively longer wavelengths. The "echo" of the explosion grows louder, however, for the total radiative power of the shell increases as it sweeps up the sparse matter between the stars.

As the radiative power of the shell grows, the energy of the individual photons emitted decreases until most of the energy of the ejecta has radiated away. After 100,000 years, just about the time it dissipates into void, the shock wave will have cooled enough to radiate in the extreme ultraviolet with the power of several hundred Suns.

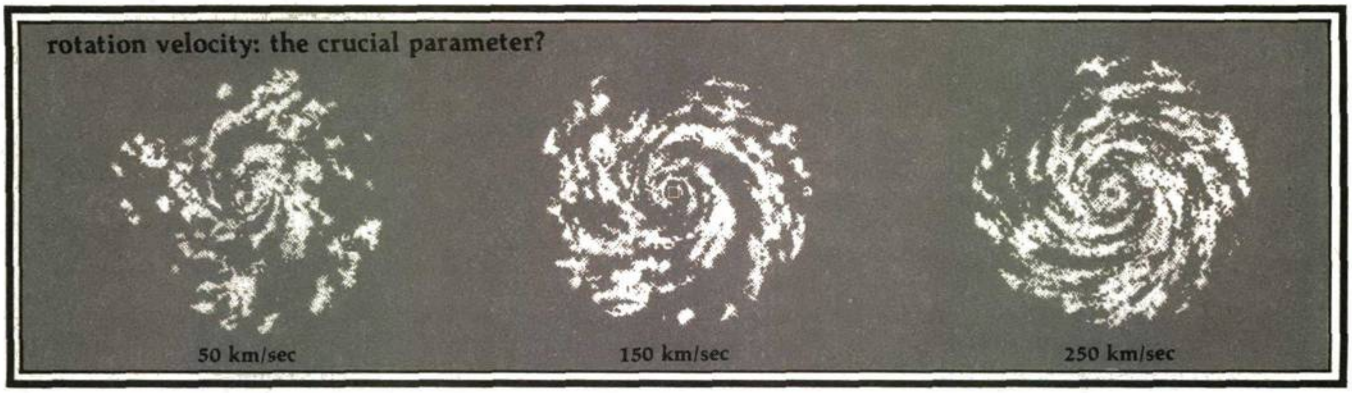
These powerful shock waves can initiate the gravitational collapse of a gas cloud and thereby trigger the formation of stars; it is reasonable to assume that some fraction of the newly-formed stars will be very massive. High-mass stars become unstable in their later lives and are likely to explode as



supernovae — triggering in turn the formation of more stars. (See "Do Supernovae Trigger Star Formation?" ASTRONOMY, April 1982.) Since a fraction of each new stellar generation thus created will be very massive, it's easy to see that supernova-induced star formation can propagate through a galaxy. When this process occurs in a differentially-rotating disk, the regions undergoing star formation lie naturally along a spiral shape.

In 1976, astronomers Mark Mueller and David Arnett of the University of Illinois devised a computer simulation to see if this self-propagating star-formation mechanism could explain the raggedness often seen in galactic spiral arms. While their model managed to generate patchy forms, the overall structure didn't resemble real spirals very well and was erased after only a few rotations. Their simulation was unable to create large-scale spiral structure unless they artificially restricted star formation to a preset spiral pattern, such as might be produced by density waves. Mueller and Arnett concluded that while self-propagating star formation is responsible for the irregular structure of some spiral galaxies and may even be the agent that rejuvenates density waves, the model breaks down in too many important details to be workable. Is it possible, though, that something is wrong with their model?

The University of Illinois astronomers had created a "deterministic" model; that is, they assumed that a given shock wave will form high-mass stars that will eventually produce new shock waves when they go supernova. But there is no guarantee that a given high-mass star will explode. And if it does, there is no further certainty that its shock wave will produce new stars: if new stars are formed, it is even possible that none of them will become supernovae.



Above: Recently, theorists have taken computer-generated model galaxies and made them mimic the shapes of real galaxies by varying only one parameter — rotation velocity. Diagram courtesy P.E. Seiden. Left: M-33 is a large spiral galaxy of Hubble-type Sc, characterized by a small nucleus and massive open arms. Lick Observatory photo.

Self-propagating star formation is really not deterministic, but a random or *stochastic* process, subject to the rules of chance.

By incorporating randomness into the simulation, two investigators at IBM's Watson Research Center were able to generate long-lasting spiral structures that closely resembled actual galaxies. The new model, designed by Humberto Gerola and Philip Seiden in 1978, suggests that star formation induced by the deaths of massive stars is capable of forming *all* spirals, not just the disorderly, patchy ones.

To visualize their model, imagine a set of rotating concentric rings. The rings of small radius rotate more rapidly than those of large radius, so that the model as a whole rotates differentially. Each ring is divided into little boxes, all of which have the same area throughout the array. Each box carries a label to identify what is going on within it: those undergoing star formation are labeled "stars"; those that initiate star formation in their neighbors are labeled "supernovae." The model operates in discrete steps of time, each of which equals one galactic rotation.

To begin the simulation, the researchers randomly filled about one percent of the boxes with stars; each star has a finite probability of inducing star formation in a neighboring box in the next time step (rotation). You can envision the resultant step-by-step evolution of large-scale structure as individual frames in a time-lapse galactic movie.

This model has the great advantage that, since new structural features are continually created, it avoids the wind-up due to differential shear. But while the simulation succeeds in creating stable galactic structures, many researchers are critical of the technique. The model ignores the gas content of the galaxy, for example. "Astronomers are wary of these computer models because they are still too simple," says William Herbst of Wesleyan University.

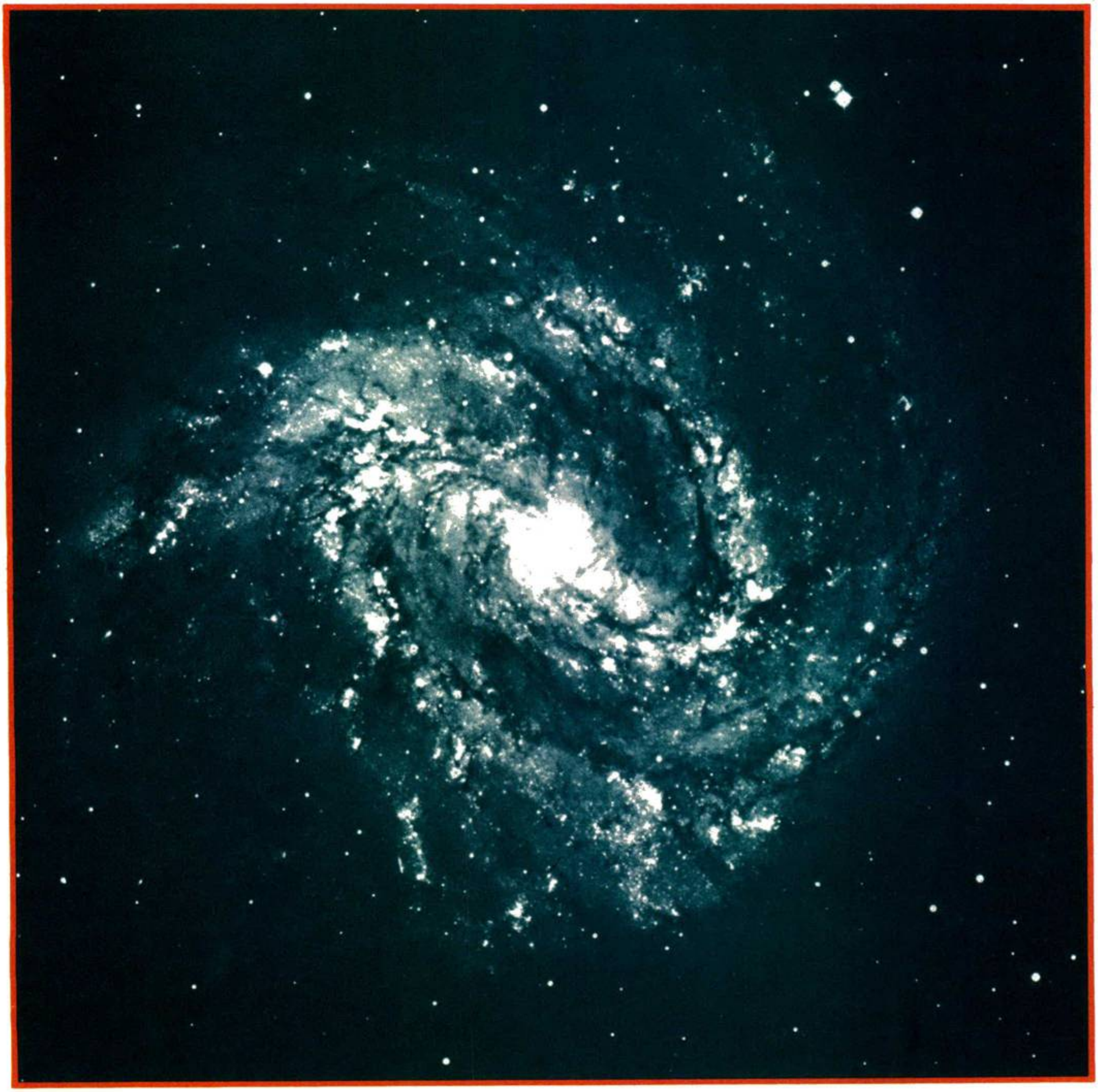
Another criticism centers around the model's sensitivity to certain variables. Good spirals are generated only when the probability of a given star creating another star falls within a very narrow range of values. If the probability is too low, spiral segments are short, sparse, and unstable; if it is too high, then the galaxy suffers a "population explosion" and rapidly fills up with stars. "To put the problem somewhat facetiously," Herbst adds, "some astronomers feel that if you juggle the numbers long enough you might get good spirals in a coffee cup."

In spite of its simplicity, Gerola and Seiden's simulation presents some encouraging results. For example, the rate of supernovae required to maintain the model's spiral structure is roughly one explosion every 50 to 150 years, which agrees well with the rate of one supernova per century deduced from surveys of galaxies. In addition, Gerola and Seiden found that the range of forms that real spirals have could be produced by the model as a direct result of different rotation velocities.

Spiral galaxies are usually classed by the openness of their arms. In the first developed, and most widely used, galactic classification system, Edwin Hubble recognized three distinct types of spirals: tightly wound (Sa), intermediate (Sb), and loosely wound (Sc). Astronomers noticed some time ago a correlation between a spiral's Hubble type and its speed of rotation — tightly wound galaxies rotate faster than those displaying loose structure. This is easy to understand in terms of the shearing force applied to the arms. Differential shear on a spiral arm is directly in proportion to the rotation velocity of a galaxy — the faster the rotation, the greater the shear. Rapidly rotating spirals *must* have tightly wound arms because their differential shear is very large.

Gerola and Seiden discovered that when their model used the actual rotation rates of a real galaxy, it produced a spiral pattern with the same characteristics as that galaxy. For example, if they used the rapid rotation of M-81, an Sb galaxy in Hubble's scheme, then the model galaxy displayed the moderate openness of Sb-type galaxies. When the slower rotation rate of M-101 (type Sc) was used, the simulated galaxy had clumpy, loosely wound, Sc-type spiral arms. Gerola and Seiden found they could reproduce the entire Hubble sequence for spiral galaxies by varying just one parameter of their model — the rotational velocity.

But gratifying as this conclusion is, the story is not yet complete, for although spiral galaxies are certainly numerous, they still constitute only about 75 percent of all known galaxies. And ellipticals, the next largest galactic family, differ from spirals in almost every way: they are predominantly reddish (which indicates a stellar population with few young blue stars), contain



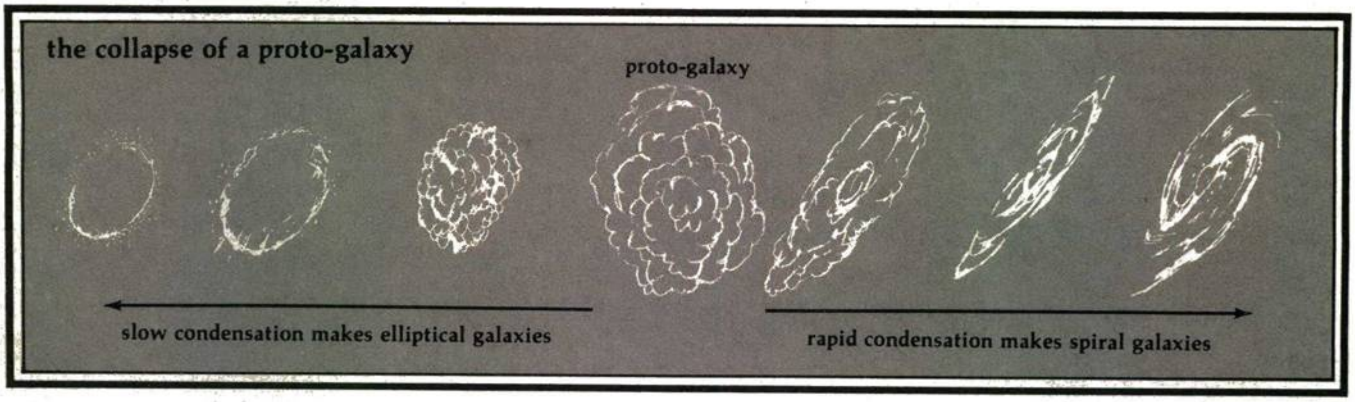
small amounts of gas, and display little or no internal structure. It's almost impossible to believe that the beautiful and dynamic spirals and the homogeneous ellipticals evolved together; yet all galaxies presumably came from the same place at the same time. How did these two extremes originate?

Seiden, Gerola, and co-worker L. S. Schulman suggest that a detailed examination of the curious properties of stochastic star formation may provide some clues. Perhaps the most familiar example of this kind of phenomenon is a terrestrial forest fire.

In a burning forest, the fire maintains itself by hopping from tree to tree. There is no way of knowing whether the flames will jump between any two trees — *only* the probability of a hop can be determined. Naturally, a major factor in determining this probability is the distance between trees. (For the purposes of the example, we'll ignore the effects of wind.) If the forest is very sparse and the trees widely separated, then the flames find it difficult to jump from one tree to another and the fire will quickly die out. But if the distance between trees is small enough, then the fire propagates rapidly and can easily consume an entire forest.

The transition between a fire that dies out and one that thrives occurs very suddenly; that is, there is a critical inter-tree distance beyond which the fire dies, but below which it easily spreads. And the rate at which the fire spreads depends on how close the real distance is to the critical value: when they almost match, the rate of spreading is slow; when the trees are much closer than the critical distance, the fire rapidly roars out of control.

The critical parameter — the "distance between the trees" — in stochastic star formation is the probability that a supernova will create a new massive


the collapse of a proto-galaxy
proto-galaxy
slow condensation makes elliptical galaxies
rapid condensation makes spiral galaxies

Above: When a proto-galaxy condenses more rapidly than its stars can form, it becomes a spiral. When it collapses more slowly, it is fated to be an elliptical. Left: M-83, a massive spiral in Hydra. European Southern Observatory photo.

star. As we saw in the computer simulation, if this probability is higher than a certain critical range of values, the galaxy quickly fills up with stars. If the probability is too low, star formation comes to a halt.

The critical probability also depends on the number of directions available for propagation. The greater the number of dimensions, the smaller the critical probability will be (or, returning to the forest fire analogy, the larger the critical distance). If, for example, a single row of trees is burning instead of a forest, the likelihood of flames hopping between any two trees is quite small. This is because each tree has neighbors in just one direction (east or west, say). In a real forest, flames can spread to the "north" or "south" in addition to "east" and "west." In three dimensions, "above" and "below" become available.

A forest is effectively two dimensional: flames are limited to the height of the trees and the fire can spread only by moving in the two available horizontal directions. Interestingly, the same can also be said of disk-shaped spiral galaxies since their thickness is so much smaller than their diameter.

Some 18 billion years ago, say the cosmologists, all matter in the universe began expanding radially away from a "Big Bang." As the universe expanded and cooled, atoms of hydrogen formed. A little later, inhomogeneities developed in the distribution of the gas atoms, and concentrations appeared. Eventually, these aggregates of gas — proto-galaxies — accumulated so much mass that they began to fall in on themselves. The density of the constituent gas of the proto-galaxy increased as collapse continued and stars began to form.

According to stochastic star formation, such a collapsing gas cloud has two possible end results. If star formation takes place slowly in comparison to the rate of collapse, the gas cloud will have time to flatten out into a disk before its gas is siphoned off into star formation. The likelihood of stars being induced to form by supernova explosions is much larger in the three-dimensional collapsing cloud. Later, when the proto-galaxy flattens into a disk, it effectively eliminates the third dimension and the rate of star formation drops off to the modest levels we observe today. Star formation remains high in the spherical central portions of the disk, which depletes the gas required to form more young stars. The result is a spiral galaxy with a population of old reddish stars in its nucleus and a disk rich in gas and active in star formation.

The second possible outcome seems to explain the very different properties of elliptical galaxies. When the proto-galactic cloud collapses slowly compared to the rate of star formation, the gas is turned into stars long before it can flatten into a disk. The formation of new stars soon grinds to a halt because there is no material left to create them. Only one generation of stars ever forms: it slowly turns reddish as it ages. Thus the galaxy appears spheroidal, contains little gas, and has a population of old stars. The IBM theorists admit that their evolutionary scheme is still quite simple, but believe "that the total picture is suggestive enough to be considered seriously."

There are presently only two theories that tie the rate of formation of stars to the overall structure of a galaxy: Gerola and Seiden's stochastic star formation and the density waves of Lin and Shu. The two are not mutually exclusive, for a changing stellar density can easily generate density waves in the gas. In order to decide between them, theorists are examining both schemes in detail to discover where they will yield differences in galactic forms; observers will then try to find what the theorists have predicted.

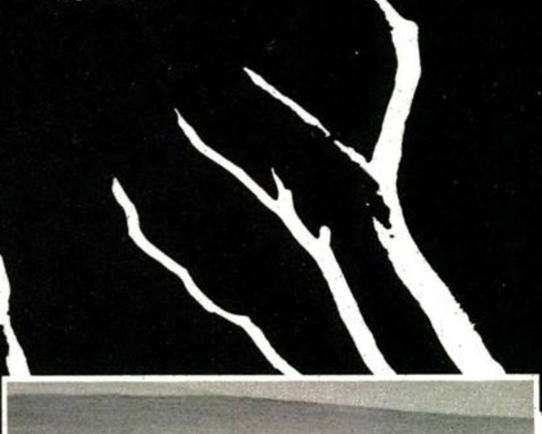
It's unlikely that either theory will account for all the forces responsible for the shapes of galaxies. "No existing theory rigorously explains spiral structure," said R.L. Pennington of Rice University. For example, the density-wave theory doesn't predict the variety of structure that astronomers observe. "It isn't the all-encompassing theory it was supposed by many to be," Pennington said. On the other hand, many theorists consider stochastic self-propagating star formation a "fringe" theory — not quite acceptable as a model for spiral structure. "Perhaps spiral arms are initiated by density waves," Pennington suggests, "and are propagated and maintained by other processes — like supernova-induced star formation."

To us, the galaxies seem to be silent works of art floating peacefully in the depths of space. Only now are we beginning to examine their sculpture in enough detail to uncover the hammerblows of the artist.

Francis Reddy's last article in ASTRONOMY was "Backtracking the Comets," which appeared in the August 1982 issue. He is now an assistant editor with ASTRONOMY.

Space Art in Hawaii

by Michael Carroll


MARS
NATIONAL
MONUMENT

A public park on Mars? Canadian artist Maralyn Vicary-Diddams created this scene of a tourist on one of the large martian volcanos.

Steam from cracks in a multi-colored crater floated gently into a dark sky. Hundreds of feet below, an immense bronze fan of cooled lava spread across the landscape, accented by the smell of hot sulfur. The scene could have been the great volcanic shield of the Beta Regio on Venus, the orange plains of Io, or the rusted summit of Olympus Mons on Mars. It was, in fact, the caldera of Mauna Ulu on the island of Hawaii. Clinging to its face on this June morning were a handful of the world's foremost space artists. They were attending a workshop designed to explore the volcanic features on Earth that may be analogous to sites on other planets and their satellites.

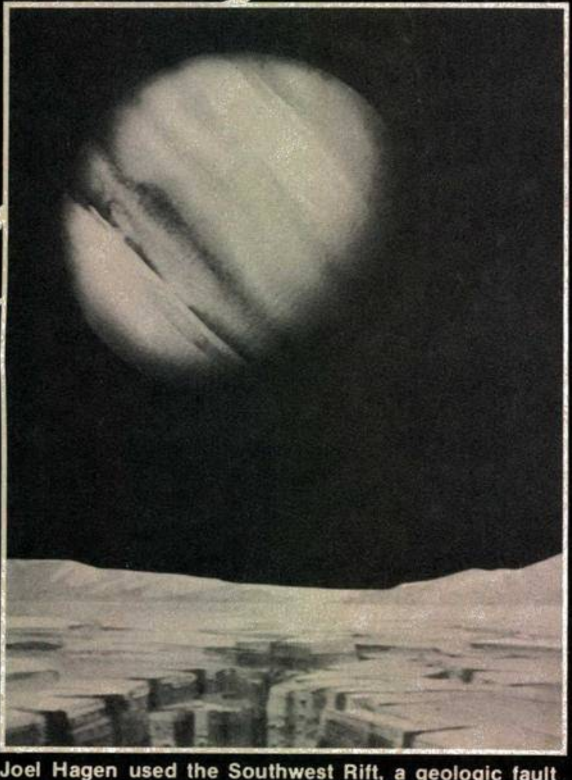
A Planetary Perspective

The island of Hawaii is an ideal location to study alien environments. In recent years, spacecraft exploration has uncovered a multitude of sites with striking similarities to terrestrial formations. Reconnaissance by spacecraft such as Voyager, Pioneer, Venera, Mariner, and Viking has proven just how volcanically active our solar system is. Huge volcanic chains rise above the ochre plains of Mars. Evidence from Pioneer radar imaging suggests that shield volcanos also exist beneath the sulfuric acid clouds of Venus in an area known as Beta Regio. Lava flows have spread across the surfaces of Mercury, our Moon, and Mars.

The analogies between our planet and other worlds become more strained as we move farther out in the solar system. Io, Jupiter's smallest Galilean satellite, is possibly the most volcanically active body in our solar system, but whereas Earth's volcanos — and those of the other terrestrial planets — expel silicate material heated by radioactive decay from the planet's core, Io erupts sulfur-based material. The volcanism of this jovian moon is driven by tidal forces generated by the push and pull of its surface by Jupiter and the other Galilean satellites.

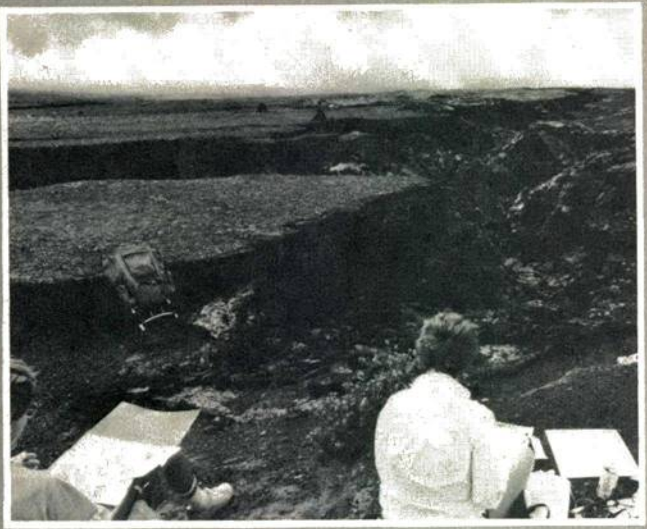
Even more exotic forms of volcanism may exist within the icy bodies of our solar system. Jupiter's moon Europa, for example, exhibits the smoothest surface yet found on any planet or moon. Some force has obliterated its original cratered surface, and mysterious fractures with little vertical relief trace a graceful calligraphy across the satellite's surface. Many of these dark linear features contain bright central ridges where liquid material — probably water — has escaped through fissures, only to freeze on the surface. Superficial analogies can be found in fracture zones on the floors of some terrestrial volcanos, as well as in ice packs at the Earth's North and South Poles. Several of Saturn's moons have distinct areas that have been resurfaced. The most extreme example is Enceladus, where eruptions have inundated cratered plains with smooth flows in the recent geological past. According to Michael Carr of the U.S. Geological Survey, the erupted material is probably not water, but a substance with a lower freezing point. Possibilities include mixtures of water with ammonia or methane.

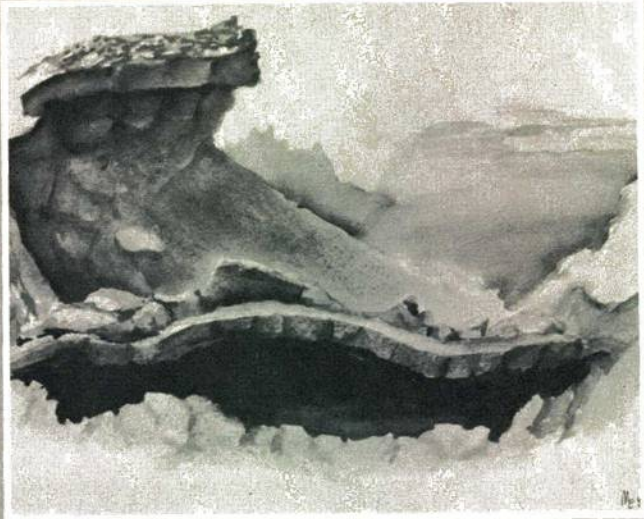
Analogies between terrestrial forms in Hawaii and those on other planets are sometimes astounding. Tucson artist Kim Poor recreated the escarpment at the base of the martian volcano Olympus Mons. The terrestrial counterpart of this feature lies at the base of Mauna Loa: a long, towering slope known as Holei Pali. ("Pali" is a Hawaiian word meaning "cliff.") Other formations, like encrusted sulfur vents, must bear some resemblances to features on Io. High atop Mauna Kea (13,967 ft.) is red soil and rock — a Mars-like surface formed through processes of erosion and oxidation similar to those working on the



Joel Hagen used the Southwest Rift, a geologic fault zone 15 miles long, as the basis for this icy landscape on a moon near a Jupiter-like planet.

All photos by author

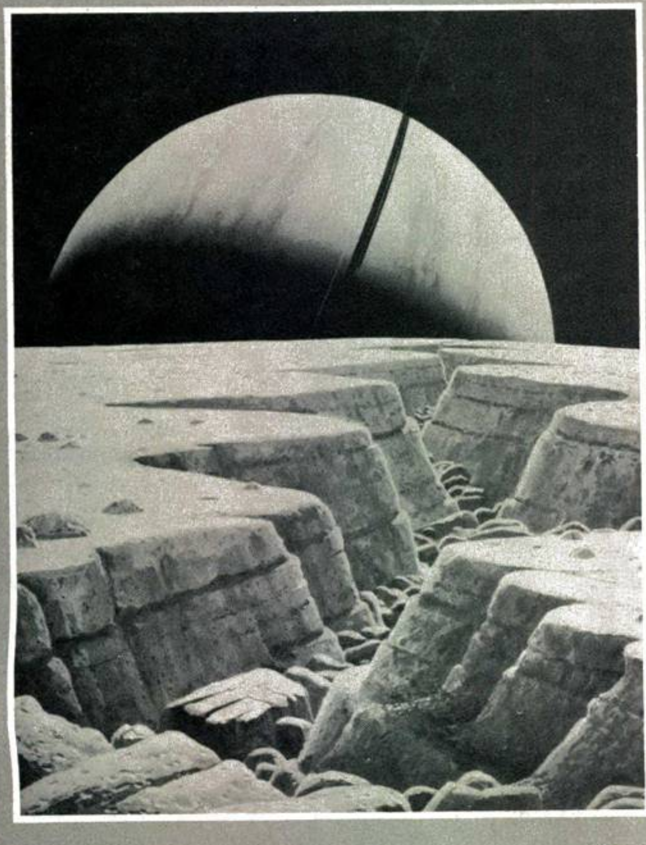




Red Planet. In an area known as Devastation Trail, chains of sink-hole craters mark the collapse of lava tubes. Similar chains are seen on the flanks of Olympus Mons and other martian shield volcanos. This phenomenon may also be responsible for some rilles — long narrow valleys — on Mercury and our Moon. In addition, some lava flows may bear at least superficial resemblance to supercooled ice flows on satellites in the outer solar system.

Anatomy of an Astronomical Painting

Desolation. That is the overwhelming feeling which permeates Kilauea Iki, the site of Magma House where the workshop took place. The trail along the crater floor winds across dark crevasses, cathedrals of pumice, and blocks of rainbow-striped lava. Banks of volcanic glass are shrouded in steam and an ominous silence. Kilauea crater looks like a seething black ocean, its waves frozen in time. From halfway up the crater rim the dark valley appears to open up into a saddle, powdered in spots with orange sulfur. Kilauea Iki, the site of the eruptive vent, towers like a mound of artist's pigment melting in the tropical Hawaiian mist. Ochres and crimsons run down into the gaping jowls of what was once a fierce lava fountain.

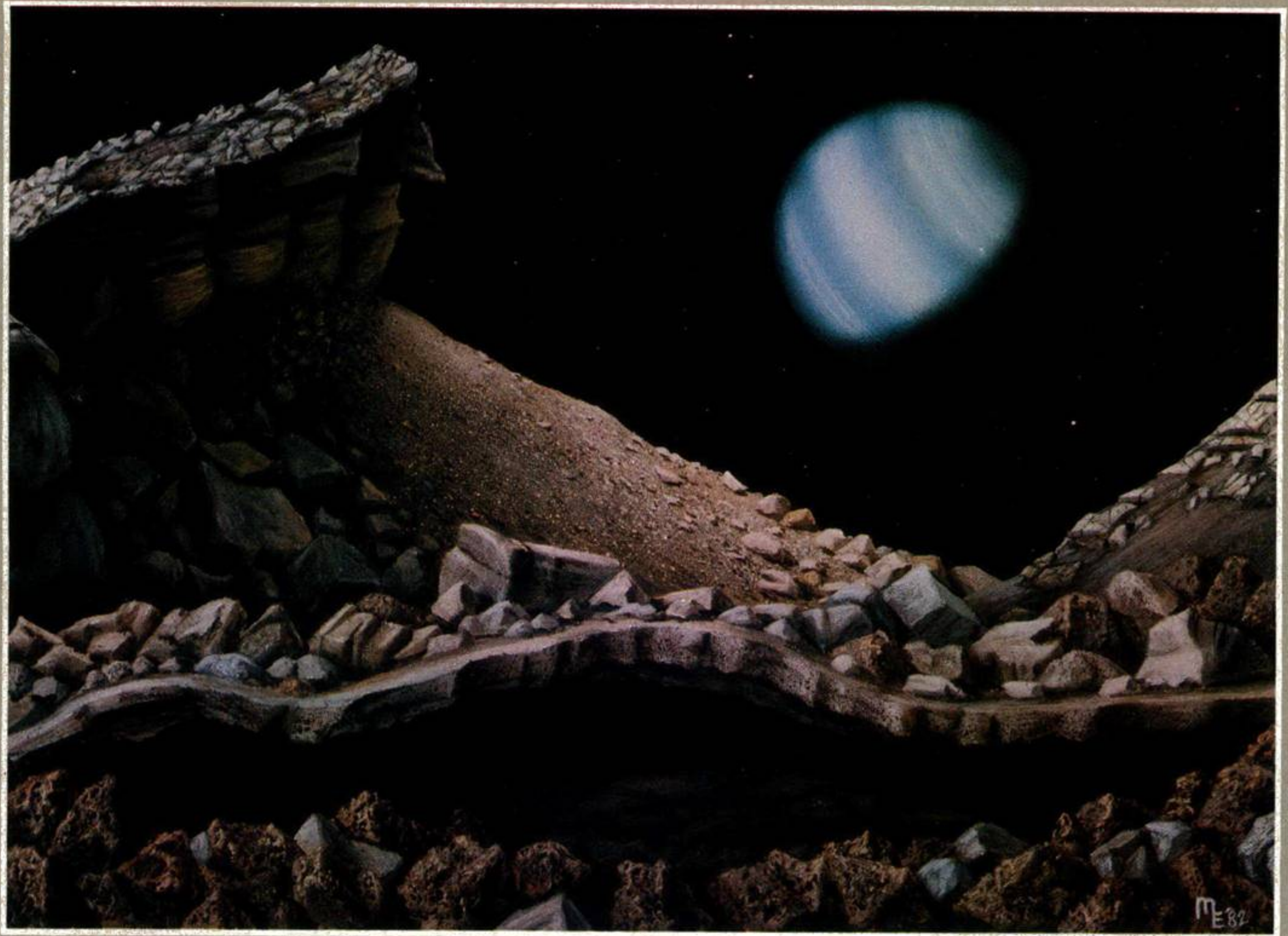


This alien vista provides a wonderful impetus for the creativity needed to do space art. But the creativity of an accurate astronomical painting must be laced within a framework of scientific knowledge. What exists in our solar system? What is possible under a given set of physical circumstances? How do the earthly formations come about, and how do they relate to their counterparts in the cosmos?

Astronomical painting is difficult by nature since the artist may never actually see his subject matter. Consequently, this type of art relies heavily on technical information about its subject. Participation by several scientists in the area enhanced the technical aspects of the workshop. Fred Klein, USGS Geologist at the Hawaiian Volcano Observatory, gave a lecture and tour of the facilities at the observatory headquarters. The artists were able to "see" the routes of the underground magma flows through Klein's ingenious computer animation that utilized data from years of three-dimensional earthquake charting. Geologist Jack Lockwood took the group to several usually inaccessible areas to see the workings of lava flows and steam vents around Mauna Ulu. Bill Heacox, astronomer at the Mauna Kea Observatory, spent nine hours showing the artists around the highest observatory in the world. In addition, various artists gave informal seminars on technique, and Bill Hartmann lectured on determining visual sizes of heavenly bodies seen from specific locations. His demonstration answered questions such as "How large does Jupiter appear from the surface of Ganymede?"

This quest for information is necessary in the space art field. Andy Chaikin, who participated in the Viking project and is now on the editorial staff of *Sky and Telescope*, said that he was pleasantly surprised at "the high level of technical knowledge this group seems to have." James Hervat, a production designer at Hummel Planetarium in Richmond, Kentucky, agreed: "I do think you need to know more about your painting topic than in other fields of art." Hervat, whose work has appeared in numerous publications including *OMNI*, ASTRONOMY, and *World Book Encyclopedia*, added, "In scientific illustration, the artist is more than just an observer — he's an educator."

Armed with creativity and scientific knowledge, the space artist must transport terrestrial observations into an alien environment with a new set of physical constraints. Maralyn Vicary-Diddams, a Canadian artist whose work has appeared on CBC television and in publications like the *Planetary Report*, went through this process at a large fault zone known as the Southwest Rift. This chasm runs from the



Maralyn Vicary-Diddams translated the fault structure known as the Southwest Rift (photo, opposite page) into an on-site watercolor (opposite, right) and finally a finished acrylic painting of Neptune's moon Triton (above). The physical processes responsible for terrestrial geologic features are probably at work on other bodies in the solar system. For a view of the saturnian moon Enceladus (opposite, bottom), astronomer/artist William K. Hartmann transported Hawaiian rift geology a billion miles away. Hartmann is largely responsible for the success of the workshop.

Kilauea crater complex for 15 miles down the coastline. Diddams made on-site preliminary sketches in watercolor, to be used later as the basis of an alien landscape — the terrain of Neptune's moon Triton. She then determined the visual size of Neptune from Triton and created a painting of the moon. Triton is a large body, perhaps as large as Callisto (approximately 2200 kilometers in radius). Its orbit is retrograde — in the direction opposite to that of Neptune's rotation — which implies that a major catastrophe changed Triton's orbit in the distant past. Such a catastrophe easily could have created cracks like the Southwest Rift. Thus specific terrestrial elements can serve as models for other planets.

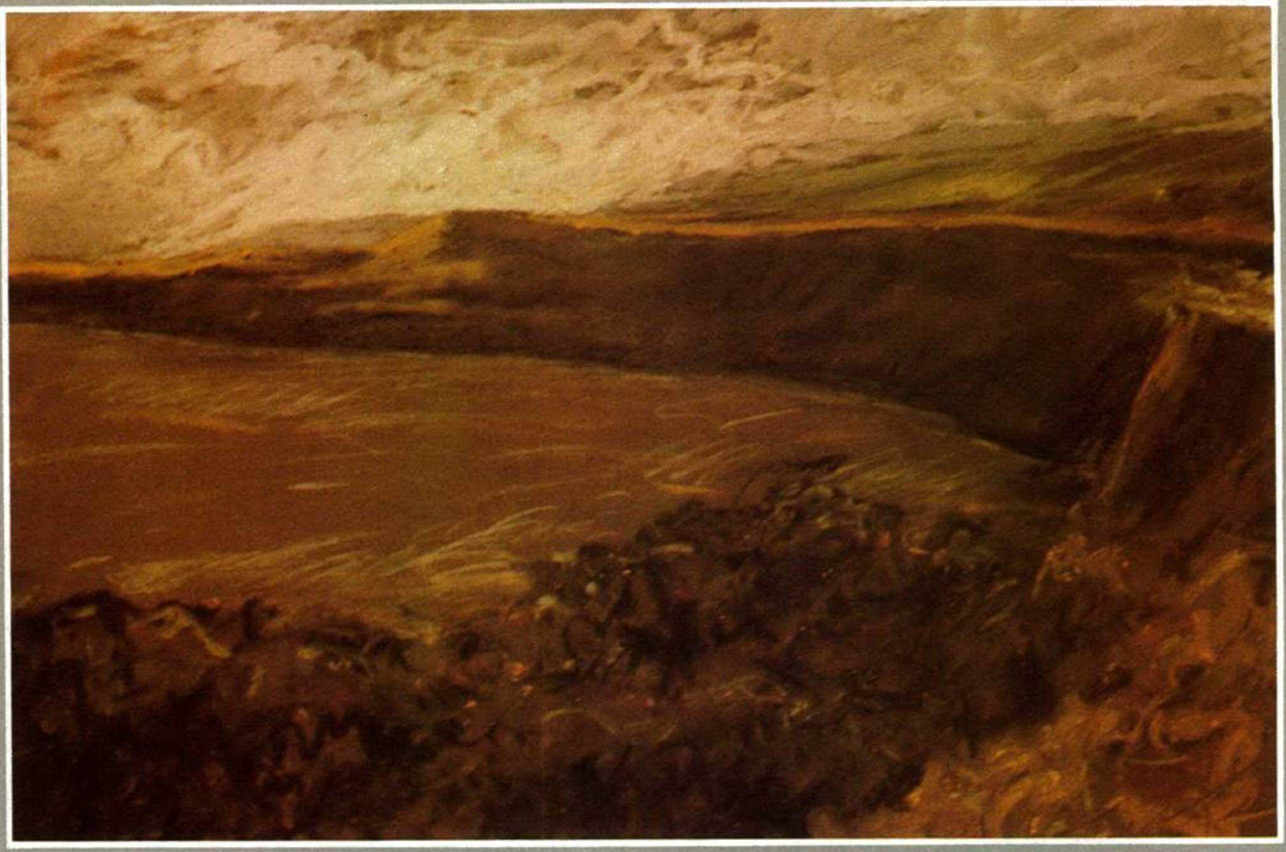
Putting It All Together

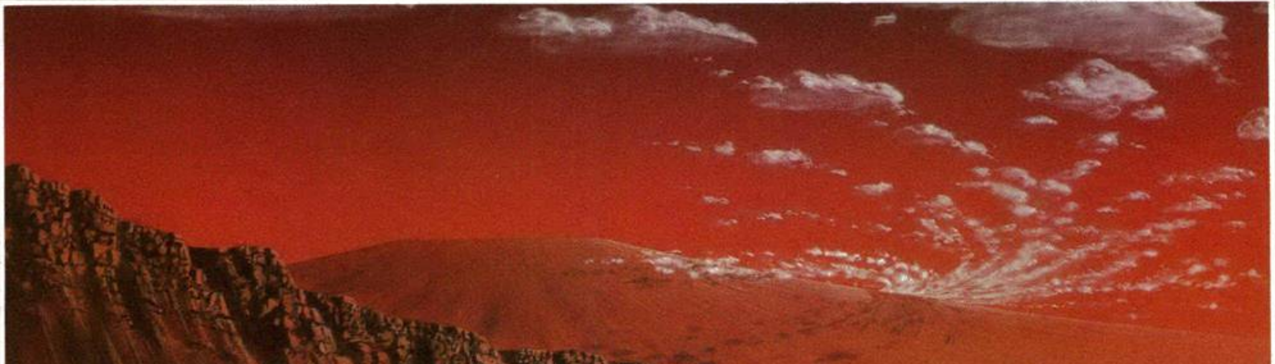
Why is space art so popular? Joel Hagen, a versatile artist whose training in anthropology is evident in much of his work, explained that "some place we haven't been before draws us out there." Pamela Lee, whose diverse artistic experience has brought her many design awards, put it another way: "I'm just a frustrated tourist who likes to paint places she would like to see." While commenting on

The First Space Art Workshop

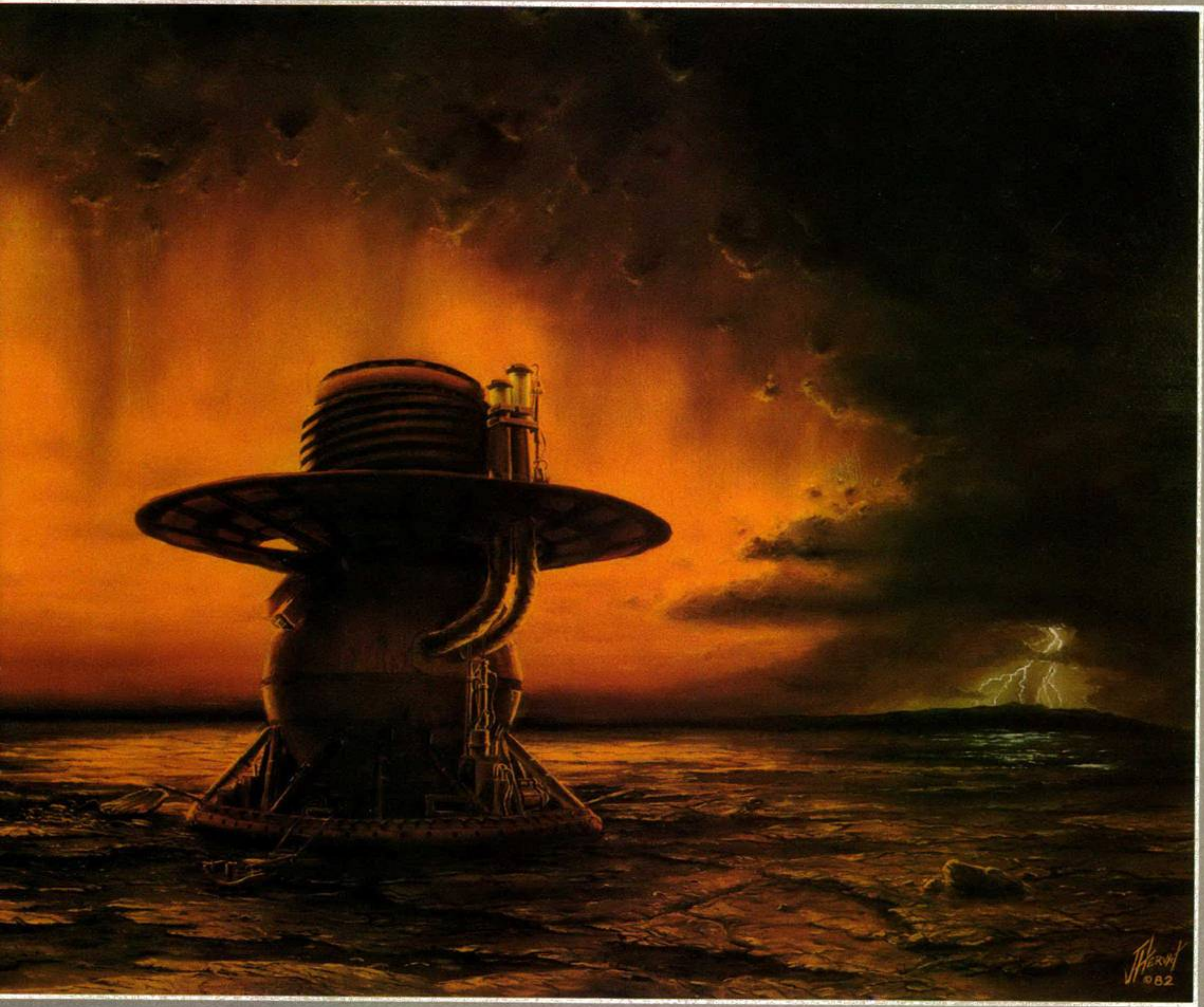
The space art workshop resulted from the cooperation of the Volcano National Park Service, the donations of time and energy from many scientists in the area, hours of assistance and encouragement from Marsha Morrison, director of Volcano Art Center, and, above all, the dedication and hard work of Dr. William K. Hartmann, who spearheaded the entire project. In addition to being a fine space artist, astronomer Hartmann is a senior scientist at the Planetary Science Institute in Tucson, Arizona. His research work brings him to the Mauna Kea Observatory on Hawaii several times a year. Since he first saw the area as a graduate student in 1964, Dr. Hartmann considered the other-worldly appearance of the area to be of potential benefit for artists in painting alien landscapes. In 1978, Hartmann met Marsha and Boone Morrison, founders of the Volcano Art Center. After showing them his art, he was invited back as guest artist for two weeks. Later, with advice from renowned space artist Ron Miller, Hartmann worked on possible grants for a space art workshop. The Planetary Society's Planetfest provided final impetus for the project in August 1981. After meeting with the largest group of space artists ever assembled, he made the commitment to hold the world's first space art workshop. The time was set: June 13-26, 1982.

Nine artists from the U.S. and Canada attended the space art workshop at Kilauea. They included Andrew Chaikin, William K. Hartmann, Joel Hagen, James Hervat, Kim Poor, Pamela Lee, Maralyn Vicary-Diddams, Mary Zisk, who is art director at *Science Digest*, and the author. An exhibition held at Volcano Art Center included works by Don Dixon and Rick Sternbach.





Top above: California Artist Pamela Lee used pastoils to create this view of the rim of Kilauea Iki. Above: Kim Poor's "Martian Palisades" depicts an escarpment at the base of Mars' giant volcano, Olympus Mons. Left: The shield volcano Mauna Loa stretches along the horizon behind the snow-capped cinder cone of Mauna Kea. Top right: James Hervat's conception of Venera 14 on Venus shows rock formations similar to eroded volcanic features. Copyright 1982 James Hervat. Bottom right: A dust storm rages over Pamela Lee's martian rift valley.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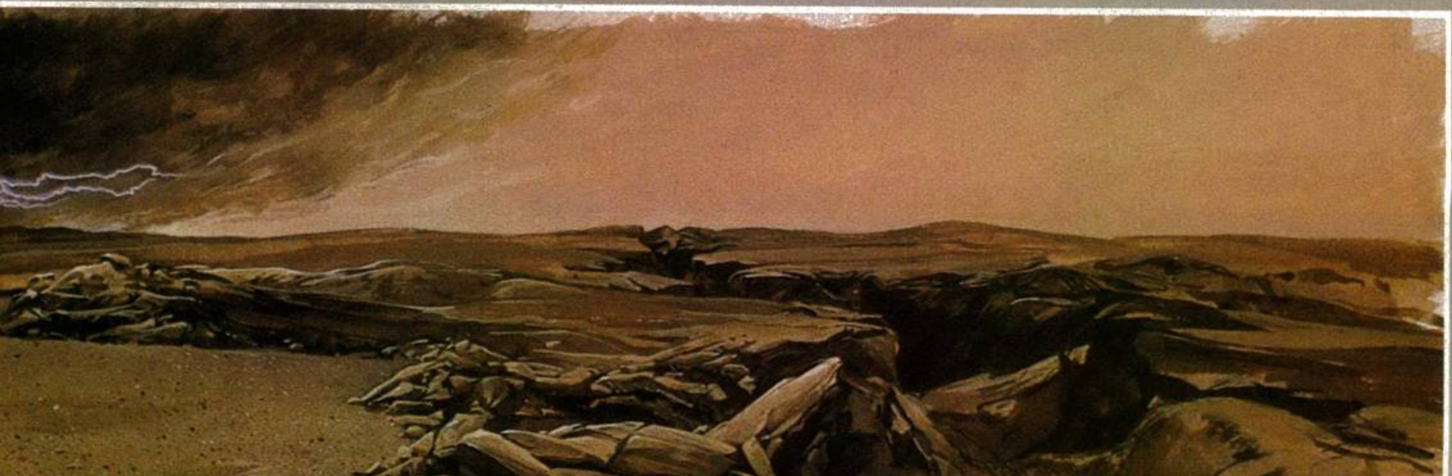
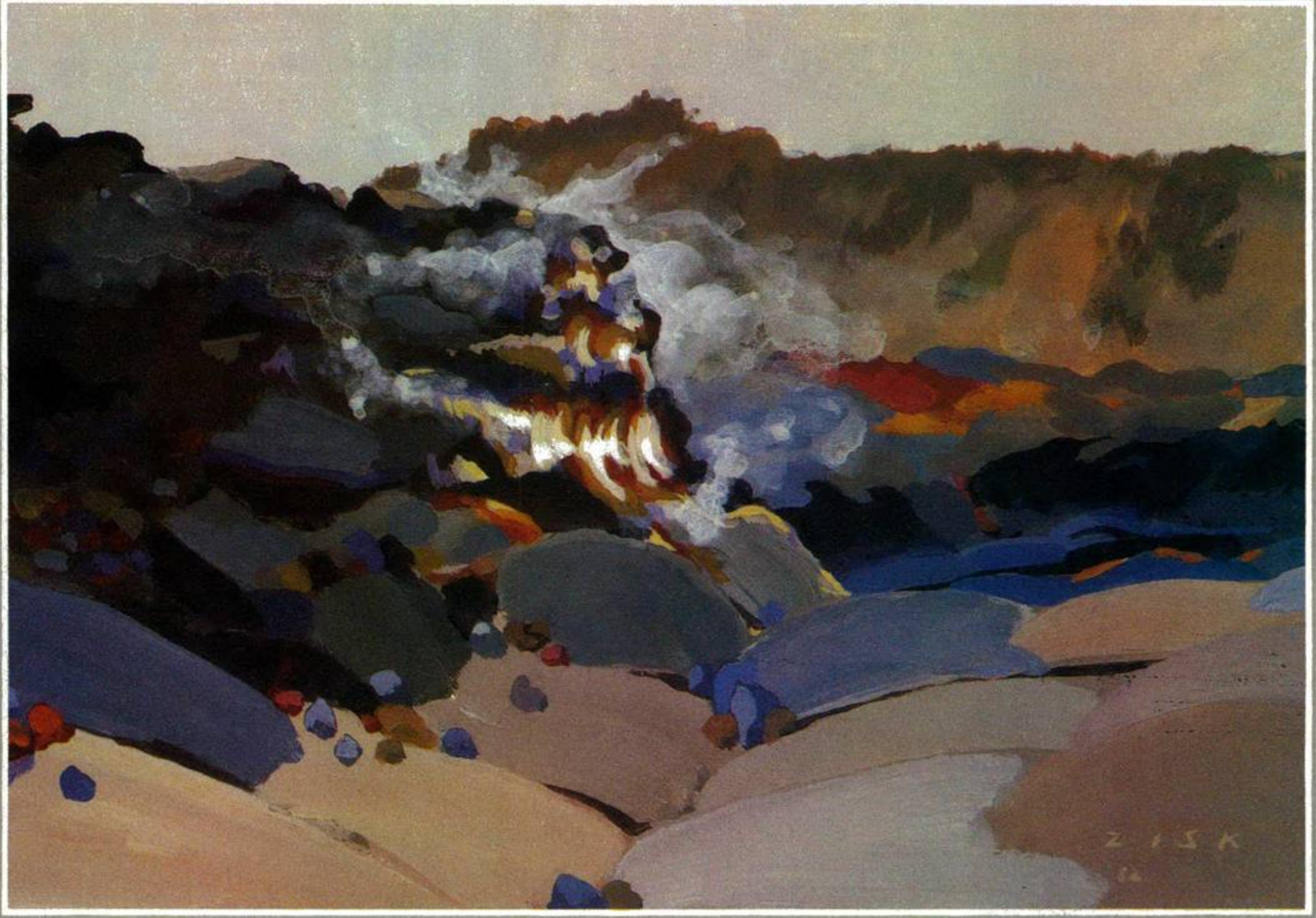
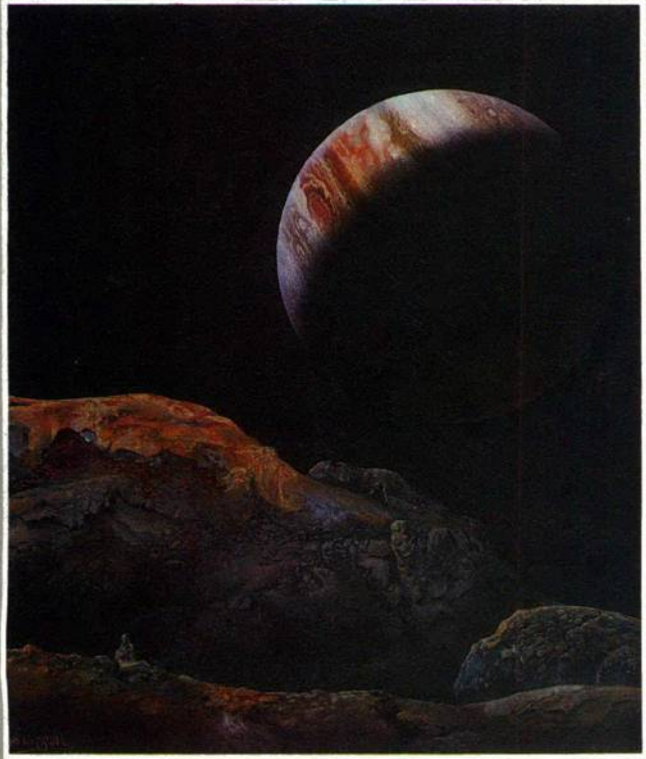




Above: Mary Zisk's impressionistic painting of steam flowing from a volcanic vent was inspired by structures at Kilauea Iki. Below: Artist Michael Carroll painted this view of Jupiter's volcanic moon Io using the rock formations of Kilauea Iki's main vent as a model.



the quality of the show, Marsha Morrison described it in biological terms. "The *edge effect* occurs on the edge of a biome or an ocean," she said. "There is more to see, a greater variety of life, more chance for evolution. You get this same thing going on at the edge of art and science."

According to Hartmann, the workshop established that a group of artists educated in the sciences exists. "They're kind of naturalists in a natural field," he said. With the resurgence of realism, space art is rapidly becoming an accepted modern art movement. This art form brings our new knowledge of the cosmos into focus for scientist and layman alike. Hartmann and others see it as fulfilling the same function in our society that the paintings of Thomas Moran did in the 19th century. Moran's paintings of Yellowstone, for example, were instrumental in obtaining the region as the first national park.

This workshop was important to the artists who attended as well as people in all walks of life who are interested in astronomy. As Hagen noted, "It's worth taking the stairs instead of the elevator, or trotting instead of walking. And it's worth it to create something. . . ." The trip to Hawaii was not easy for many, but it was worth it to the artists who were able to attend. The great French landscape artist Ingres said, "He who calls upon no mind except his own will soon find himself reduced to the most wretched of all limitations, namely, that of his own works." This group of talented people took the time to look out from behind their charts, sketchbooks, and scientific journals to see the lessons that nature has left at our feet. Their work provides a glimpse of the new worlds that will be an important part of the future of humankind.

Michael Carroll is a staff artist at the Reuben H. Fleet Space Theater in San Diego. His last painting for ASTRONOMY was the title spread of "Looking Inside Quasars" in the November 1982 issue.

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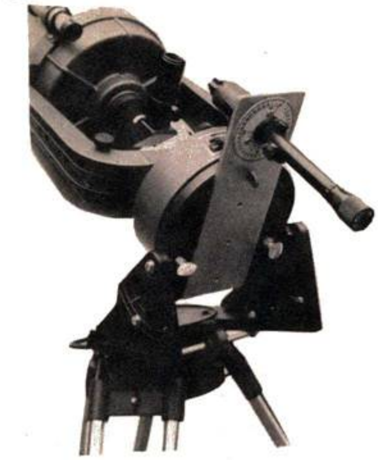

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Voyager: Technological Totem

"What's happening here?" asked ASTRONOMY's Editor during the Voyager 2 encounter with Saturn.

As the weeks and months pass into years, I have often pondered that question. My thoughts go back to the excitement and the record heat of Southern California in the summer of 1981. He asked the question while we were sitting in the press room at the Jet Propulsion Laboratory in Pasadena two evenings after Voyager 2's closest encounter with Saturn. The room was almost empty; the feverish activity of the preceding days had died down.

We had watched the closed-circuit television screen count off the hours, minutes, and seconds until the closest approach to the ringed planet that night. Hundreds of cars had clogged the parking lot and the street leading to JPL as people waited expectantly, watching the digital clock and the succession of photographs — waiting for what, precisely, they did not entirely know. It resembled New Year's Eve: a moment in time designated as important, although it is actually indistinguishable in most ways from those which preceded and those which followed.

Yet we gave it meaning.

The long-awaited moment of closest encounter was an instant that fell not at an even hour, such as midnight or noon, but rather at the messier moment of 8:25 p.m., Pacific Daylight Savings Time, Tuesday, August 25, 1981.

It would be an hour and a half before actual word from Voyager could reach us across the billion miles of space to confirm that it had indeed arrived at that point of closest approach. The message would be further delayed because that point was hidden behind the planet, so the radio messages could not even be started on their way until after Voyager had emerged from the occultation.

What was happening here? Thousands of people had focused their interest on an inanimate object more than a billion miles away, an object they would never see again — neither they nor any human, nor probably any other sentient beings in our family of planets. Only a fraction of them had actually seen the craft before it left Earth four years earlier, so they had not had an opportunity to develop a first-hand affection for this ungainly-looking Voyager.

Yet there they were, hundreds of technicians, scientists, reporters, secretaries, and security personnel gathered at JPL. A thousand press passes had been distributed to representatives of media, ranging from reporters for obscure journals in obscure towns to the famous faces seen nightly on CBS, NBC, and ABC television news.

> **"Voyager was a totem: it affected our lives, had admirable qualities, and possessed extraordinary powers . . ."**

A few miles away, in the Pasadena municipal auditorium, thousands of others attended the Planet Fest, saw exhibits, and heard reports on the past, present, and future of space exploration. Across the nation and around the rest of the world millions more followed Voyager in the mass media.

Why were they interested?

Voyager did not carry people, nor creatures of another species, like ET, with whom we could identify and interact. Voyager is not alive and does not even look like a living being. Voyager lacks the anthropomorphic appeal of R2D2 and other personable humanoid machines. It is an inanimate object, and a spindly one at that, without the smooth aerodynamic features found in fictional and real spacecraft from Flash Gordon to the Space Shuttle.

Voyager, in fact, lacks intrinsic value of practically any sort. It has little worth of its own. It is a conglomeration of rods and wires, gears and relays, of plastic, metal, and glass. There is little about it that would bring wealth to a celestial scavenger interested in precious metals, little to bring its finder riches or power. In centuries past, merchants had also been concerned about the fate of distant craft which they hoped would bring back wealth, such as spices and silks from far-off Cathay and Cipangu — but this Voyager will never return.

Instead, it serves other functions. The most obvious is that it sends us information about new worlds and wonders never before seen at close range. It has already sent us thousands of measurements of Jupiter and Saturn, and may also give us information about even more distant worlds — Uranus and Neptune.

But there is another, less obvious aspect of Voyager. Voyager is, in some ways, a totem. A totem is an object, animate or inanimate, that is regarded by a group as having a special relationship to that group. Primitive peoples attributed extraordinary powers to their totem, and believed that it would assist them. While today we are more sophisticated, several totemic aspects of Voyager may be noted.

The totem can be a central element in the social organization of

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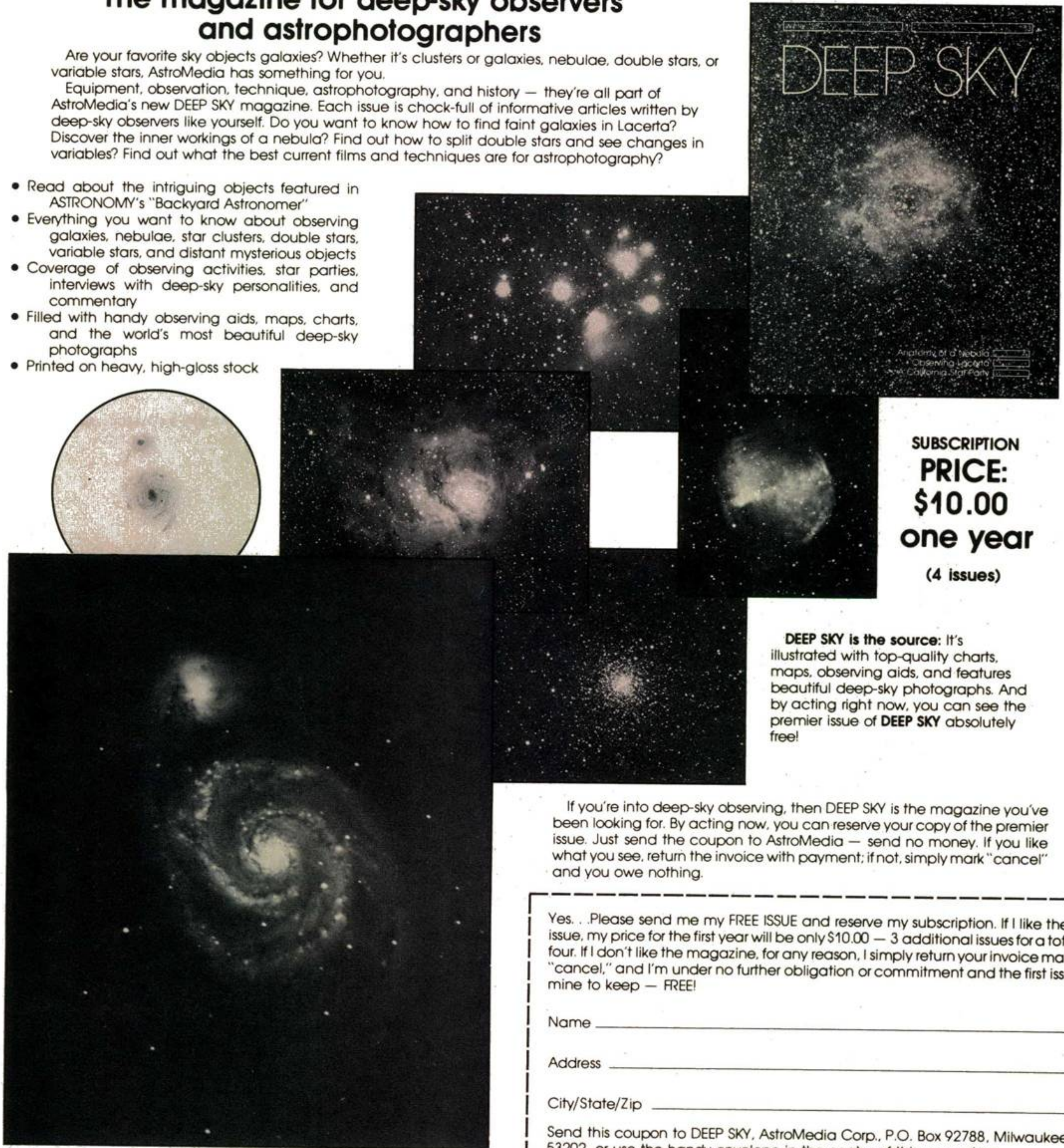

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a group, providing a focal point around which people can gather. The totems of primitive religions were an important factor in developing cohesion within early societies. In our time, Voyager, particularly at the Jupiter and Saturn encounters, was a center, a common ground around which many groups and thousands of people gathered. Some of these groups have lasted for years — the Voyager science teams, for example. Others, like the crowds at JPL and the Pasadena Planet Fest, were momentary. Regardless of the duration of the group, whether long-lasting or short-lived, people were brought together by their shared interest in Voyager.

Their interest is reminiscent of the veneration primitive people had for their totems. We don't worship Voyager, but we do have positive feelings about it and concern for its well being. This was particularly evident in the apprehension felt as Voyager flew behind Saturn, out of radio contact for several hours, in the relief when it emerged on the other side, and in our subsequent dismay when we learned that something had happened to the scanning platform.

Why were people concerned about Voyager? At least three elements of totemic belief may be detected here:

1. It affected their lives.
2. It had admirable qualities.
3. It possessed extraordinary, supernormal powers.

Voyager affected people vocationally and recreationally. For some people Voyager provided jobs. Many others with no occupational connection were fascinated by it and by the data it sent to us from distant worlds. Information from Voyager has already affected careers; reports of its findings, presented at professional meetings and published in journals, bring prestige, tenure, promotion, and perhaps research grants. Voyager also had some less favorable consequences, as people devoted so much time to it that their spouses complained of neglect. And the loss of data from the jammed scanning platform meant that some planned reports could not be published. We will never know all the effects of Voyager, but the point is that Voyager did have an impact upon individuals while it was here on Earth, and still does, now that it is a billion miles away and hurtling ever farther into space. Its impact is due not to any magical power but simply to the fact that it was involved in some way with people's lives.

A second totemic element of Voyager is that it stands for the positive aspects of our civilization, particularly of our science and technology.

While we devote billions of dollars to ever-more-terrible weapons, Voyager flies on a mission of peace.

Instead of polluting the environment and consuming Earth's limited resources, Voyager glides through space using gravitational forces of other planets.

In a world rife with greed and sensual desire, Voyager provides intellectual challenges by sending us fascinating data about distant worlds.

In a world full of deceit, corruption and trickery, Voyager is free of hidden motives. It breaks no campaign promises; it makes no surreptitious political deals.

Few heroes are evident today, and Voyager is perceived as partially compensating for this dearth. Voyager represents some of the finest aspects of our civilization, with admirable qualities too often missing in prominent humans.

Third, there are the extraordinary powers of Voyager, which not long ago would have seemed like magic. One of these is remote viewing — the power to look beyond the normal limits of human vision, to see events in distant places, which was a cherished dream of primitive sorcerers. This dream persists as one facet of present-day parapsychology. Yet the reality of Voyager far surpasses the wildest hopes of past magicians and present mystics. Voyager sends us close-up pictures of objects more than a billion miles away, of rings and worlds and other wonders whose very existence was unknown to the ancients.

A final totemic aspect of Voyager is immortality — immortality for the totem itself and, in a sense, for us, too.

Voyager will not die. It is exempt from the degenerative aging processes of living matter, and it is also spared the erosive effects of planetary atmospheres. All terrestrial creatures eventually expire, and even inanimate monuments as vast as the pyramids of Egypt slowly weather into dust. Outer space is free of these hazards, though it does have others, including radiation and meteors. Apart from a collision, however, there is little to diminish Voyager's "life expectancy" of a million years, or even more.

In addition to an extremely long life for itself, there is immortality in another sense. Voyager may bring us immortality, not for individuals or even for our species, but for our existence and our accomplishments on Earth.

In only a few years, the spacecraft will have left the solar system entirely, to travel perhaps for eons in interstellar space. If intelligent beings eventually find it, they may wonder where it came from and who made it. In this respect, Voyager may be viewed as an extension of ourselves, carrying with it our hopes for immortality, a wish that our labors and our existence will someday be recognized, perhaps long after we and Earth have vanished.

I am not implying that we relate to Voyager in the same naive manner as our ancestors, but merely that our actions retain traces of ancient social processes. This is not surprising; in spite of the changes wrought during the intervening millennia, we still face some of the fundamental problems that confronted early hominids; though our dangers take a different form, they are very real.

Now, at the dawn of the space age, we may be experiencing some of the same forces that impelled our remote ancestors to leave their familiar habitats and venture into the unknown. Voyager encounters, while celebrating a marvel of modern technology, also included elements going back thousands of years into the past. The encounter had meanings at multiple levels. While the participants were aware that it was an important event, few realized the full significance of our amazing technological totem.

David Swift
Honolulu, HI

Non-Astronomers Are People, Too

At the party, you reply, "I'm an astronomer," and someone gushes, "Oh, wow! Would you do my horoscope?" Or, hoping for apocalypse, a couple ask, "Will anything happen when all the planets line up?"

You say, "No."

Somewhat disappointed, they then ask, "Well, when will it *not* happen?"

Yes, my friends, there are non-astronomers out there — people who think Beta Lyrae is a new rock group and ultraviolet is a new toothpaste.

You *could* deal with this by locking yourself in your room and vowing never again to communicate with alien creatures. After all, if they

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But wait! If you engage in hibernation, you'll only be robbing yourself and them of some very rewarding experiences. Talking about astronomy can be a most enjoyable thing for you. And even though people usually don't know much about astronomy, most are readily intrigued and fascinated by it. It's even possible that you might spark someone's interest so much he or she might decide to pursue it more deeply. And, of course, increasing even *one* person's knowledge about astronomy will make a small contribution toward enhancing public suport for the troubled space program.

Let's face it: astronomy has a lot going for it. It has to be one of the most exciting disciplines there is — certainly far more interesting to most people than any other science and one heck of a fine hobby, too. Where else can you deal with such things as the possibility of other forms of life, the death of the Sun, and the existence of black holes?

Unfortunately, astronomy also has a lot going *against* it. People tend to think that anything purporting to study every object in the universe must be incredibly complicated and certain to be entirely incomprehensible. Many people are just vaguely aware of all the astronomical jargon — spectral type, magnitude, parsec — and it immediately turns them off. In addition, a good many were exposed to it sometime in school in a manner which very likely bored them. People aren't going to ask you questions about something they think they won't ever be able to understand or enjoy.

But that's where you come in! In a few minutes, you might succeed in eradicating some or even all of their apprehensions and help them begin to appreciate what a wonderful science astronomy is.

But you can't just say anything. Although how you deal with non-astronomers depends to some extent on their level of intelligence, some general guidelines should help ensure your success.

First: sound interested. This shouldn't be hard if you have a deep and natural love for the stars, but if you don't, you'll only bore them.

Second: avoid jargon. Jargon is necessary for astronomers but it's not needed for others. Use common language. Keep your explanations simple without being simplistic.

Third: respect their intelligence. Remember that whatever their ignorance, you once knew no more yourself.

Now let's pretend you're in a small, informal gathering of non-astronomers and you're fielding some of the commonest inquiries. One thing people always seem to wonder about is extraterrestrial life. Although most people realize that intelligent life on Mars is rather out of fashion these days, that still leaves a lot of territory open.

"Do you think there are people out there?"

You could give a quick "yes," "no," or "maybe" to that, but they'd be more interested if you supplied a few details. Tell them of the need for a star of the correct temperature with planets about it. You'd be surprised — a lot of people think all stars are just like the Sun; some don't even know the Sun is a star. Mention the need for appropriate climate on these planets. And stress the uncertainties in our current knowledge of how easily life evolves even under such ideal conditions — that gives people a better feel for what astronomy is and how astronomers think.

Another thing people are always worried about is the Sun. Admittedly, it's a sensible thing to be worried about: it ultimately powers all life on Earth. But for some reason, an awful lot of people seem to think it's in imminent danger of exploding.

"Increasing even one person's knowledge of astronomy will make a small contribution to the space program."

"No, no," you reassure them, "that only happens to bigger stars."

They look greatly relieved.

"Instead, it'll expand into a red giant and totally engulf the Earth."

Either they look uncomprehending, or panic strikes. Parents grab their children and look nervously out the window to see if it's already started.

Maybe some brave soul, expecting the worst, will ask, "When is this supposed to happen?"

"Oh, in five billion years — give or take a couple billion."

A very good idea in astronomical explanations is to use analogies to clarify the point you're making. Not just any analogy will do. First, it has to be simple, otherwise the analogy will be tougher to explain than the thing you're really trying to explain.

To illustrate, let's take a real favorite among non-astronomers: the ever-popular black hole. A lot of non-astronomers have figured out that astronomers are a bit embarrassed by these things. After all, if they don't emit any light, how do you know when you've found one? Some people even hint broadly that it's a thinly disguised scandal in the astronomical community, sort of a "Cygnusgate."

"Well," you say, "pretend you're in the bathtub and you let the water out. It spirals down the drain. Now the same thing happens with a black hole: matter spirals down it. As the matter circles the hole, it rubs against other infalling matter. This friction produces heat, and it gets so hot. . ."

"How hot does it get?"

"So hot it emits X-rays — the things your dentist makes a million dollars off of. Now, one day somebody decided to launch a bunch of X-ray satellites. These satellites detect X-rays from black holes. The most famous black hole is called Cygnus X-1."

Lest they remain uncomfortable about the existence of something they can't see directly, point out that the wind is equally invisible to them, but they know of it with certainty by its influence on other things.

Needless to say, this hardly exhausts the list of things interested people will ask about — but I feel satisfied if I've given you just one idea of how to handle those questions. Nobody's ever really comfortable, but if you're really successful and spark someone's interest, you may even hear this:

"Where can I find out more about these things?"

I usually recommend ASTRONOMY, and if I have a couple of copies handy, I let them look at them. The pictures impress. The universe is beautiful. "Neat! I didn't know pictures like this existed," they'll say. Another favorite of mine is Timothy Ferris' highly readable book, *The Red Limit*, and, of course, everybody should take a look at *Galaxies*. I might recommend a couple of others, too.

It's also a wise idea to forewarn any newcomer to astronomy that he or she won't be able to understand everything at once. Counsel them to have patience — assure them such problems happen to everyone, "Even me." You can say, "After all, how will you know you're learning something unless you discover things you didn't know before?"

But most importantly, be sure they know astronomy for what it really is — and not for the jargon. The jargon is a means, not the end. True astronomy is the stars, the planets, the galaxies, and the universe. Wonder, curiosity, and awe.

Who could resist?

Ken Croswell
Florissant, MO

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ASTRONOMY IN FOCUS

Constant Whining

Sir / I have had enough.

I am weary of the constant whining about how meager the space budget is, and about how wondrously productive a much larger budget would prove to be twenty or thirty years from now.

I happen to be one of those incorrigibly backward people, the bane of the astronomical community, who believe that spending billions of dollars each year for space probes and whatnot is not necessarily appropriate in a country in which no fewer than 200,000 people do not have so much as a roof over their heads.

It certainly is not surprising that the well-fed people who compose the space lobby cover their apathy to the hideous evils in this country with the pretension that only through an expanded space program can these evils be solved; comfort often tends to hinder objectivity and honesty. What is a little surprising is the increasing vehemence and indignation with which they put forward their phony and insulting arguments (though I suppose one might have expected this after the Voyager successes), and their failure to give even lip service to the fight against the injustices that cry out to be redressed not decades from now, but today.

In short, for all the space community's self-adulation as a champion of progress and enlightenment, the evidence seems rather conclusive that in fact it is, by and large, a crowd of self-indulgent jerks.

If you want more money for space (as I do, believe it or not), but wish to avoid the stinking hypocrisy in which you have immersed yourselves up to now, I strongly suggest that you plump for sizable reductions in the "defense" budget, whose only real purpose is to bring humankind ever closer to extinction. Digging deep into that trove would probably yield more than enough cash for both welfare and space.

I will not be renewing my subscription when it expires next year.

Robert Becker
Baltimore, MD

Putting It Together

Sirs / As they read President Reagan's platitudinous remarks on the occasion of *Columbia*'s fourth landing ("Reaganspeak," ASTRONOMY Forum, October 1982), astronomy enthusiasts should recall the admonition of former Attorney General John Mitchell: "Watch what we do, not what we say."

In only two years, Reagan has forced the scrubbing of Halley's Comet mission, canceled VOIR, eliminated nearly all basic space research, sentenced the Pioneer missions to a premature death, and unilaterally abrogated international cooperation between the United States, Japan, and our European allies. Now, Bruce Murray ("Bruce Murray Speaks," ASTRONOMY Forum, September 1982) and Clark Chapman ("FY '83 Planetary Exploration Budget Cut," ASTRONOMY, May 1982) suggest that Reagan intends to turn JPL into a doxy for the Defense Department.

Even Murray Weidenbaum, Reagan's recently-resigned chairman of the Council of Economic Advisors, has confessed that none of this is compelled by "budget cuts." Despite all the ballyhoo about the budget, Reagan is not "cutting," he is only "shifting" about $46 billion a year to the military side of the ledger. These funds more properly should be spent on civil space exploration, education, basic physics research, and social programs that provide the necessary foundation for a truly vigorous and inquisitive culture.

ASTRONOMY does its readers — and the nation at large — a great service by reporting the facts behind Reagan's philistine policies. Keep up the good work.

John C. Barrett
Des Moines, IA

A Perseid Fireball

Sir / This year's Perseid meteor shower was a spectacular one for me. Although I am a relative newcomer to astronomy, I witnessed what I think was an unusual event.

I work late at night and so I hadn't had a chance to use the small Schmidt-Cassegrain telescope I had recently borrowed from a friend; I had been dying to try it out. Finally, on the night of August 15, I got my first real opportunity. The sky was clear, the seeing relatively good, and the Milky Way shone brightly against the night sky.

Sometime between 9:50 and 10:15 p.m. (MST), I was looking down at the August Sky Almanac when suddenly the whole landscape around me turned an eerie blue-green color. Whirling around and looking up, I saw a brilliant white fireball streaking northward. It was at least as bright as the Full Moon — it drowned out everything else in the sky.

A blue-green, smoky trail flowed out behind it, quickly turning yellow-orange as the meteor slowed near Cassiopeia and burned out. I thought I caught a glimpse of some small meteors accompanying the fireball on either side and in front of it, but I'm not sure. In any case, it was a sight I'll never forget!

James Maxwell
Ririe, ID

Big Brother Is Watching

Sir / After reading AstroNews this month, I felt compelled to write. The article, "U.S. - Soviet Space Cooperation Ends," gives the reader a lot to think about. It reminded me of the years I spent as a ground-radio communications specialist with the U.S. Air Force in the Orient. I can't tell you exactly where I was stationed (for 5 years after my discharge, I couldn't obtain a passport or visa for overseas travel), what our mission was, frequencies, antennae configuration, or equipment characteristics, but suffice it to say the USAF security service carefully monitors every radio transmission behind the Iron Curtain. At the time the press was praising the Apollo-Soyuz Test Project as an example of "friendly" U.S./Soviet cooperation, we knew that the Soviets had every available missile trained on the vessels — ready to destroy both if they felt the need to do so! It angered me then and still does that the military, no matter whose, could hold such absolute sway over science, especially space exploration.

Now our government has joined the military in holding a knife to the throat of science through severe budget cuts. You'll notice the military isn't on the chopping block. Quite the contrary — admirals and generals are assured of even more military hardware. But don't get me started — I'm as patriotic as the next guy, maybe more so because I still feel we've got the best country in the world, all things considered. I only hope to God our economy will turn around so we can continue to show it to the rest of the world.

Philip A. Douglas
Bluff Springs, IL

Space Politics

Sirs / Concerning your Forum article (ASTRONOMY, September 1982) by Ross Simons on "Pro-Space Politics": Having long been active in both astronomy and politics, I applaud the article for providing a sorely-needed primer on how to get involved in the democratic process, but Mr. Simons made a rather sweeping statement when he directed those looking for a candidate's name to "call a local labor hall for the names of Democrats, and the Chamber of Commerce for the Republicans."

Although that may be an effective method in some areas of the country which are dominated by old-line politics, I feel some readers might get better and more straightforward information by resorting to other sources. Why not refer readers to one source for all their questions? The local county clerk has the same information, and most areas have a chapter of the League of Women Voters — and, if all else fails, they can try the government teacher at their local public school.

Hopefully, we can blaze new paths with an open mind, and not presume anyone's party affiliation just because they're a member of a labor union or concerned about the economic growth of their area.

Grady Blount, II
Corpus Christi, TX

Small Scopes are Portable!

Sir / Glenn Chaple's article "The Big Eyes of Small Scopes" in the October issue is a well-written ego booster for small telescope owners. The table of objects for these smaller instruments is a useful guide for users of telescopes of all sizes.

Although Mr. Chaple praised portability as an aid to quick setup, he might also have mentioned how easy it is to take these scopes out into the country. A small telescope beneath a dark sky will outperform a large, metropolitan-based one. I own instruments of 2.4, 6, and 12-inch apertures and would not part with any of them. I have used the "little guys" often to escape the menace of artificial lighting from our nation's capital.

Curtis W. Roelle
Gaithersburg, MD

Gliese's Catalog Available

Sir / When Peter Koch asked for a list of nearby stars (In Focus, June 1982), you referred him to Wilhelm Gliese's *Catalog of Nearby Stars*. Unfortunately, the work is hard to find unless you are near a large astronomy library. However, Prof. Gliese has kindly provided me with an updated version of his list, and I would be glad to send a copy to any reader who sends me a return envelope.

Jay M. Pasachoff
Hopkins Observatory
Williams College
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Ooops!

In December's Photography in Astronomy, Paul Missall — not Missal — took the picture of the Full Moon on page 52.

behind the scenes

the comet is coming!

As I write this, Comet Halley has just been photographed, or "imaged," with a solid-state charge-coupled device, "probably the best 'chip' in existence," at the focus of the 200-inch Palomar Mountain telescope. Only a week ago, Dave Jewitt and Ed Danielson, of Caltech, became the winners of an unofficial, unacknowledged, but nonetheless fierce competition to recover "The Comet."

Halley is a pretty special comet. It's bright and active as comets go, still fresh enough to do everything a comet can do. Yet its orbit is so regular that after 70 years, it was recovered within 10 seconds of arc of its predicted spot, and a mere 10 hours behind schedule.

Halley is going to be the most intensively investigated comet of all time — and the first ever to be greeted and explored by spacecraft from Earth.

Halley is now a dark, icy body only about three kilometers across. It is some 11 astronomical units out, just detectable by the world's second-largest telescope. In the next three years, the Sun's gravity will pull it in past Earth. Its tail will spread millions of miles as it zips around the Sun, then its speed will fling it back toward the stars.

We won't see it very well from the northern hemisphere: "It'll look like Kohoutek," said one comet scientist. But "Halley Fever" is growing already.

It used to be said that comets foretell the fall of princes, but we don't believe in astrology and there are no princes in the United States.

So perhaps it will fall to this comet, this starry messenger, to awaken a nation to the stars. Three years is a long time — when The Comet is coming!

Sincerely,

Richard Berry

Richard Berry
Editor

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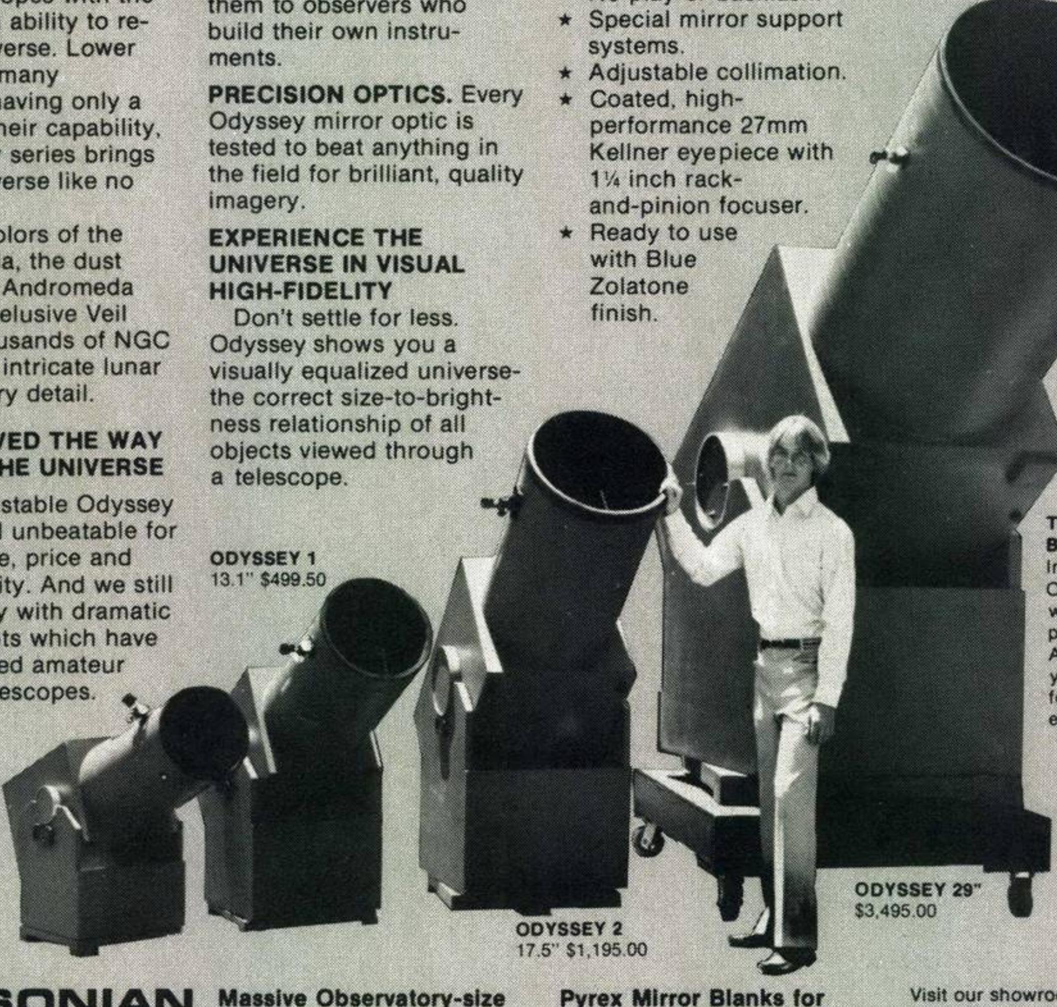

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getting the most from slide films

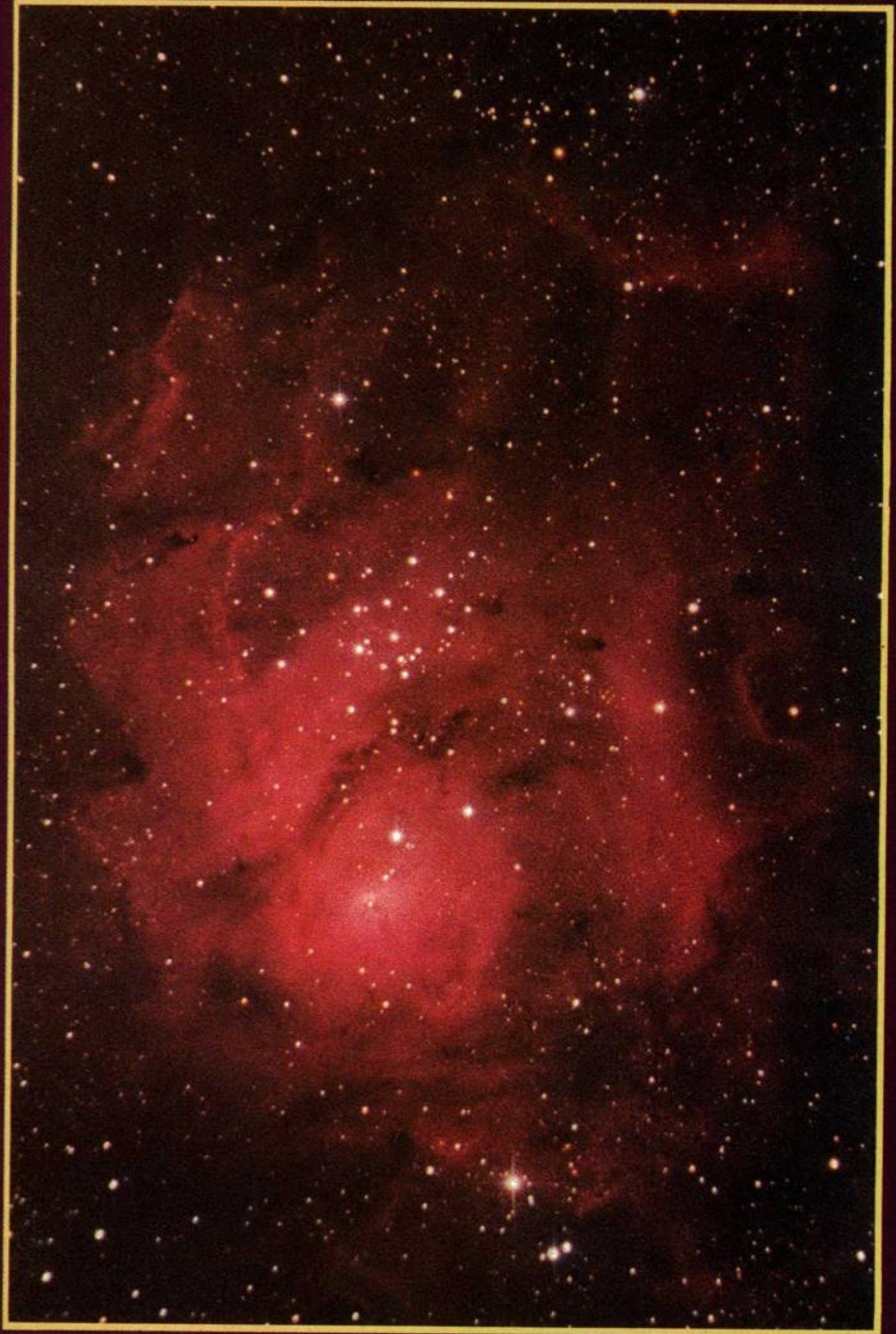
photography in astronomy

by Roger Sliva

The last two years have seen dramatic changes in the structure of astrophotography. During the '60s and '70s, telescope design and film quality severely limited the quality of astrophotographers' work. Although good 12-inch mirrors were available, and some observers could buy spectroscopic film, the average photographer had a mediocre 6-inch scope and Tri-X. Mechanical imperfections in both commercial and homebuilt telescopes doomed many would-be astrophotographers to poor results and disappointment.

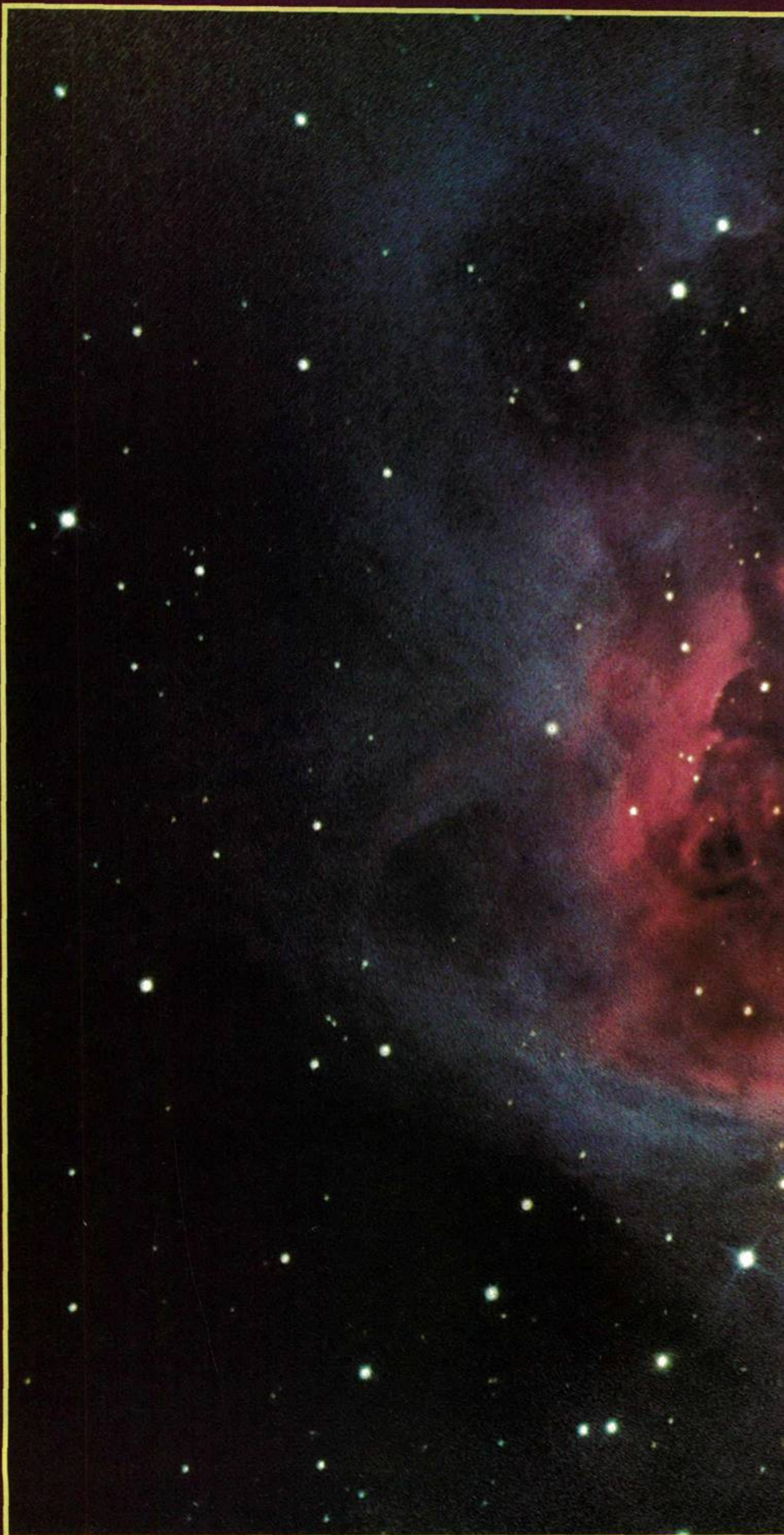
But the 1980s have brought about a completely different climate for those who wish to record the sky on film. Telescopes can now be assembled more accurately. You can buy a big Schmidt-Cassegrain, put it on a big fork mount, and be in business very quickly. In addition, techniques for film hypersensitization have become popular and practical during the last couple of years. By using hypered Fujichrome RD 100 or Ektachrome 400, the reciprocity failure problem — a film's decreased sensitivity to faint light after a few minutes of exposure — is significantly alleviated. And you can now develop color slides, negatives, and prints at home with ease.

The two most popular color films for astrophotography are currently Ektachrome 400 and Fujichrome 400. These slide films have very high speed and can be commercially developed with some degree of safety. Hypersensitizing these films improves their speed to the point where an exposure of over 30 minutes with an



This fine photograph shows the Lagoon Nebula, a massive HII emission region, and its accompanying Bok Globules. It is a 20-minute exposure on hypersensitized Fujichrome 400, made with a 12.5-inch f/5 Newtonian. All photos in this article are by the author and were developed as negatives using the Unicolor K-2 process.

This spectacular photograph of the Great Orion Nebula shows a wide range of color — from the white and red hues of hotly-glowing hydrogen to the softer blues of light-reflecting interstellar dust. It is a 25-minute exposure on hypersensitized Fujichrome RD 100, made with a 12.5-inch f/5 Newtonian reflector.



f/5 system starts to fog the film with skylight. Since 30 to 40 minutes is as long as most of us are willing to peer into a guiding eyepiece, the films are ideally suited to backyard astrophotographers.

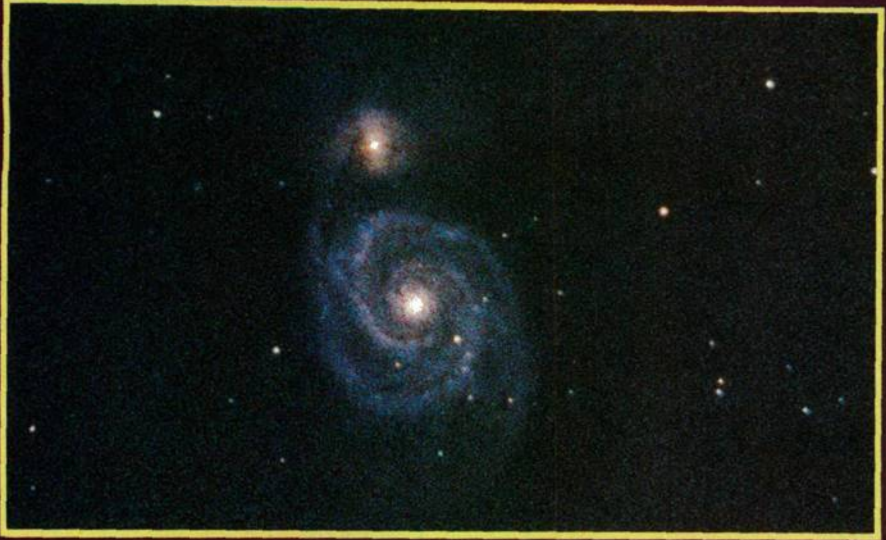
Hypersensitization is becoming somewhat routine among devoted sky photographers. (See "Hypersensitizing," Parts 1 and 2, ASTRONOMY, April and May 1981.) There are two basic methods of hypering film — closed-cassette and open-reel — both of which are quite practical. Although open-reel sensitization is considerably faster and preferred by many photographers, short film strips containing less than ten exposures can be easily hypered in a carefully-wound cassette.

I've recently compared Fuji RD 100, Fuji 400, and Ektachrome 400 in hypersensitized astronomical exposures, and have come up with some interesting results. All of my test films were hypered in a cassette with forming gas — a mixture of 92% nitrogen and 8% hydrogen — heated to 32°C at 15 p.s.i. The sensitizing times were 96 hours for Fuji RD 100, 80 hours for Fuji 400, and 90 hours for Ektachrome 400. All photos were taken with a portable 12.5-inch f/5 Newtonian.

Although no new, faster films have become available in the last few years, you can still improve the speed and quality of color deep-sky shots of faint nebulosity or galaxies. Instead of normal developing via the E-6 process, develop your slide film as a *negative*. The gain in color contrast is spectacular.

Developing Fuji RD 100 as a negative is not new. Some local photo labs do this to make complementary-color title slides for graphic arts customers. You can do it easily at home with the C-41 chemicals available in the Unicolor K-2 developing kit. I suggest that you increase the development time from the recommended 3¼ minutes to 4 minutes, and reduce the "blix" treatment — bleach, fixer, and stop bath — from 6 minutes to 2 or 3. You can complete development of the exposed slide film into negative form in only 10 minutes.

The two best films for this process appear to be Fuji RD 100 and Fuji 400, each having its own particular advantages. I have also tried the very fast Ektachrome 400, but its color balance shifted considerably toward



NGC-5195 is a small galaxy that has passed close to M-51, the Whirlpool Galaxy, drawing matter from the large spiral. This photograph shows both the yellow nuclear regions and the bluish spiral arms very well. It is a 30-minute exposure on hypersensitized Fujichrome 400, using a 12.5-inch f/5 Newtonian.

yellow: to achieve a black sky background on a print from Ektachrome 400, I needed a yellow filtration in the amount of 2.00. Since most acetate color printing filter sets contain 1.55 yellow filters, you would need two sets for the process.

The Fuji negatives use more basic printing techniques. When comparing the various films for color balance, your personal taste in colors of nebulosity will determine which film you like best. Fuji RD 100 exhibits good color balance and an excellent blue response, which is valuable for galaxies and reflection nebulae. It's a relatively fine-grain but fairly slow film, and can be used for all objects — although sky fog limits exposure times to less than 30 minutes at f/5. You can expose the film slightly longer with a nebular filter.

further printing notes

1. Use a standard stop bath (not included in the Unicolor K-2 kit) after the developing step to prevent streaks in the prints.
2. Keep all developing times and temperatures the same for each print to avoid slight changes in color balance.
3. Judge print color balance in combination light of both fluorescent and incandescent light.
4. Make test prints to check for exposure and color balance by moving a large black card across the paper at specific intervals (5 to 10 seconds). The less-exposed portion reveals sky color.

In contrast, Fuji 400 is strongly red-sensitive. Objects that show a pronounced blue color remain blue, but may shift toward a blue-purple; very faint blues are lost. Galaxies remain blue with a reddish color in the knots. But Fuji 400 performs well with other objects — its greatest advantage is the speed gain over the other emulsions. Globular clusters are spectacular in 5 to 10-minute exposures. Best of all, faint objects that could only be captured with black and white film can now be recorded in color.

Oddly, standard color-negative films are not very useful when hypersensitized. For example, Fujicolor 400 shows a marked gain in speed, but its color balance shifts heavily toward the blue.

Hypersensitized color films may never equal the sharp images of 2415, or the speed of the specialized spectroscopic emulsions, but they *do* offer some important advantages. Besides the obvious ability to separate the incoming light into colors, a tremendous amount of information is embedded in the emulsion. In a black and white negative, stars can be lost in a bright region of nebulosity. On color film, however, a faint star will register in a different color than the nebulosity, and can be brought out by an old photographers' technique called "burning in" — adding extra amounts of exposure to the dense parts of the photo when you make a print.

Why should you develop your transparency film as a negative instead of a slide? After all, projecting a color negative of the Orion Nebula at a club meeting will get a big laugh with its yellow-orange sky and green nebulosity. But if you compare a negative side by side with an equally exposed slide, the negative will show more detail due to its higher speed and contrast. In fact, a beautiful slide can be made from the negative by copying it onto another negative film such as Kodak's 5072 Vericolor film. The procedures for copying in color are the same as black and white, with one exception — color-compensating filters are necessary. This is time-consuming but very rewarding. Another way to get a slide is to make a print and photocopy it.

Prints from negatives are easier to make, less expensive, and show more detail than prints from slides. The sky background on an astronomical slide is dark with white stars. Long print exposures are needed for the enlarger light to pass through and separate the dark sky from the faint nebulosity. While this is happening, huge amounts of light pass through the white stars, which enlarges them on the print. A print from a color negative exhibits just the opposite behavior. Sky and nebulosity are better defined, and the enlarger light passes around the dark negative stars to give pinpoint images. One criterion for judging the quality of a print is how small its star images are; good quality prints with small star images are very impressive.

Perhaps the most important variable used in color-negative printing is the brand of enlarging paper used. Kodak Ektacolor 78 paper has good balance, but Unicolor RB paper has better color contrast with richer reds and blues. Prints can be developed rapidly with the two-step chemistry from Unicolor.

The most difficult part of color printing is finding the correct color filtration for a particular negative. No two negatives are exactly alike. Reasons for variations include film developing procedures, sensitizing times, and telescope exposure times. A filter pack of .30 magenta and .80 yellow is a good starting point for the average negative, but 1.50 yellow is not uncommon. Remember: if the print is too yellow, add yellow filters.

The purist may want to try for a slightly green sky to match sky fog, but a black background is more attractive. Since the sky on this type of print is the fastest part to change color, the nebulosity colors are little affected by minor filtration changes.

The decision to develop slide film as a negative is yours. If you want color images that rival your black and white prints, give it a try.

Roger Sliva is Associate Professor of Auto Body Technology and Chairman of the Mechanical Trades Department at Riverside City College in Riverside, California. His last article for ASTRONOMY was a two-part story on "Hypersensitizing," in April and May 1981.

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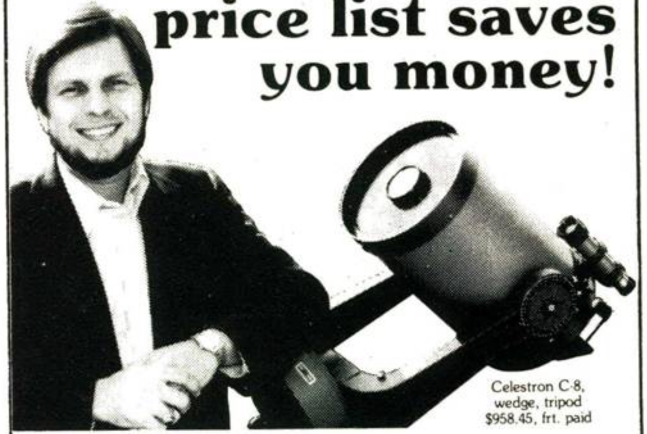

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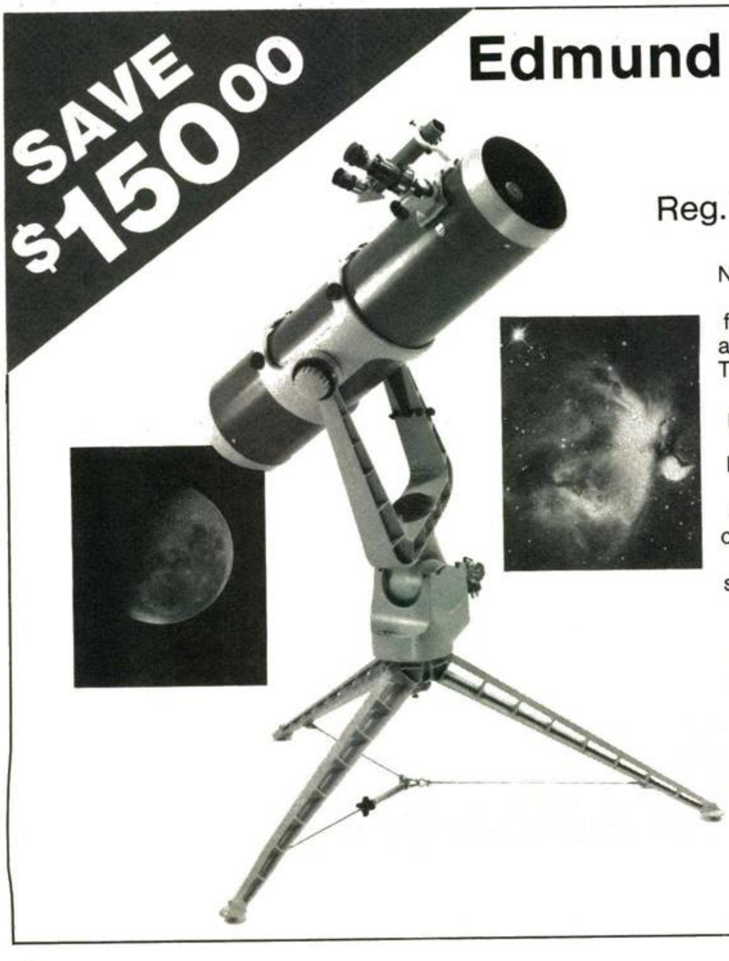

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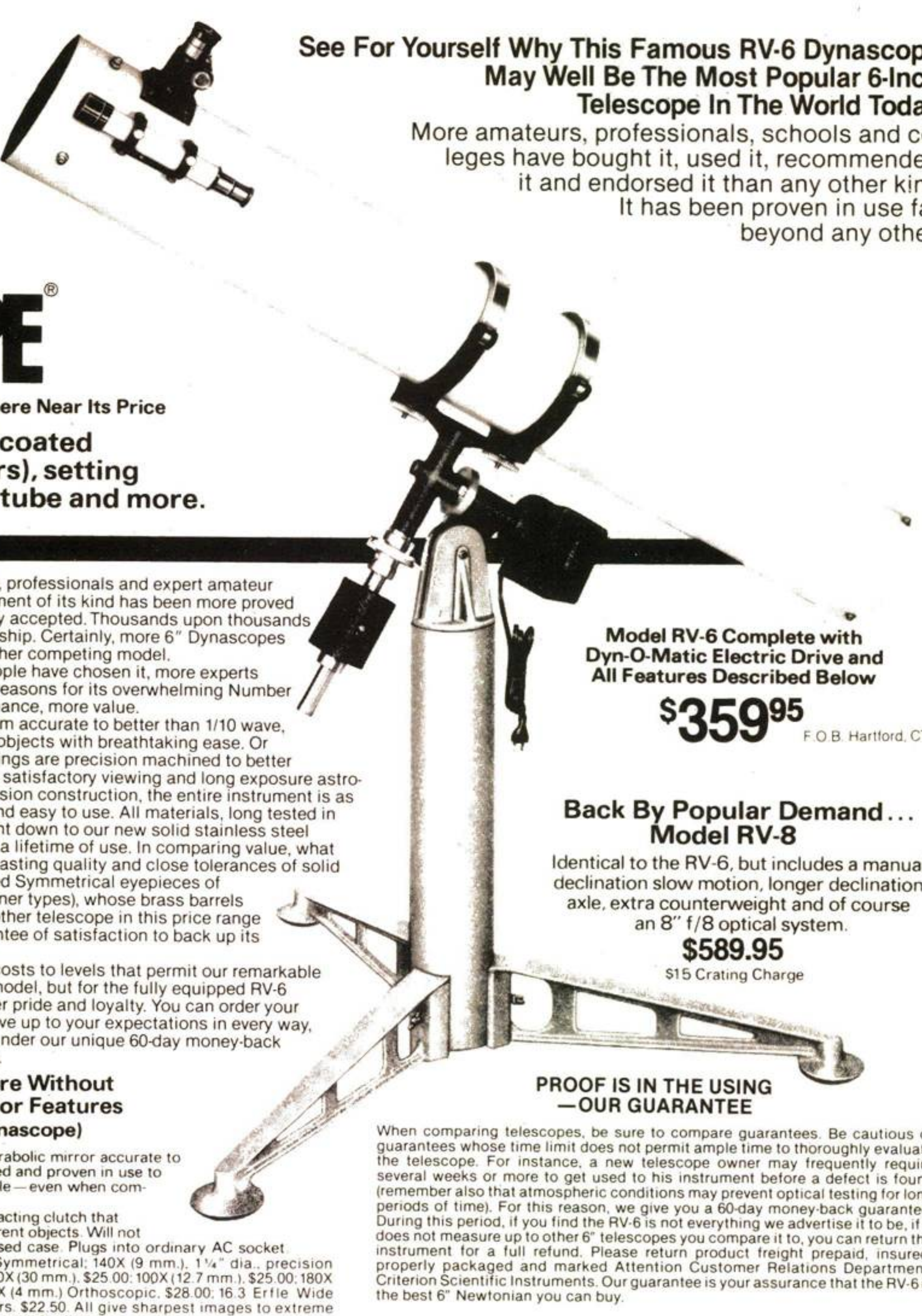

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eye on the sky

jupiter gleams in scorpius

by Fred Schaaf

the wanderers

Most of the night now belongs to the bright winter constellations, but the dusk and pre-dawn skies are well adorned with emerging planets. This year's area of continuing planetary interest will be the region of Scoprius, where Jupiter and Uranus will encounter one another three times in a region rich in stars and clusters. For naked-eye observers, the most striking conjunctions may be Jupiter's three very close passages of bright Beta Scorpii — the first of which takes place this month.

Since winter has just begun, however, Scorpius does not start rising until the beginning of morning twilight. Let us instead begin our planet survey as night falls. In the opening days of 1983, naked-eye observers will find Mercury and Venus a fine pair in the afterglow.

Mercury was at greatest elongation well above Venus on December 30, but now appears lower each night. As the planet swoops toward us and toward our line of sight with the Sun, it presents more of its dark side to us and fades quickly. Mercury reaches inferior conjunction on the 16th and then shoots out into the morning sky to become a poorly-placed object in the pre-dawn sky at month's end.

As Mercury dips toward inferior conjunction in the first half of January, it passes just over 2° north of **Venus** as seen from North America on the evenings of the 6th and 7th. Brilliant Venus now gains altitude; and, though faded to a "mere" -3.3 — about a magnitude and a half brighter than any other planet ever gets — it begins to increase in radiance again late in the month. By the end of January the "evening star" will stand at over 20° from the Sun and your view of it will profit from the steepening angle of the ecliptic. (See page 81.)

Farther eastward on the ecliptic — well to the upper left of Venus — is **Mars**, now distant and dim. This planet fades to magnitude +1.4 during January, but moves eastward rapidly enough to lose only a little ground to the pursuing Sun, still more than 30° from Mars as the month ends. Viewers with binoculars may wish to look for 5.9 magnitude 45 Capricorni just north of Mars on the evening of the 8th; observers in England should see the star little more than 2 minutes of arc away from Mars as darkness falls that night.

Orion's Brightest Stars

	Apparent Mag.	Distance (l.y.)	Luminosity (Sun = 1)
Rigel (β Ori)	+0.1	900	57,000
Betelgeuse (α Ori)	+0.5	520	11,000
Bellatrix (γ Ori)	+1.6	470	4,000
Alnilam (ε Ori)	+1.7	1,600	40,000
Alnitak (ζ Ori)	+1.8	1,600	35,000
Saiph (κ Ori)	+2.1	2,100	50,000
Mintaka (δ Ori)	+2.2	1,500	20,000

In several important respects, this year will be about the worst possible for observing Mars through a telescope. The planet is finally overtaken by the Sun for a June conjunction, and will have brightened only to +1.4 (at a 75° elongation) by year's end. But brightness and angular separation from the Sun are not everything; Mars will be involved in three conjunctions with Venus this year, one of which is very close.

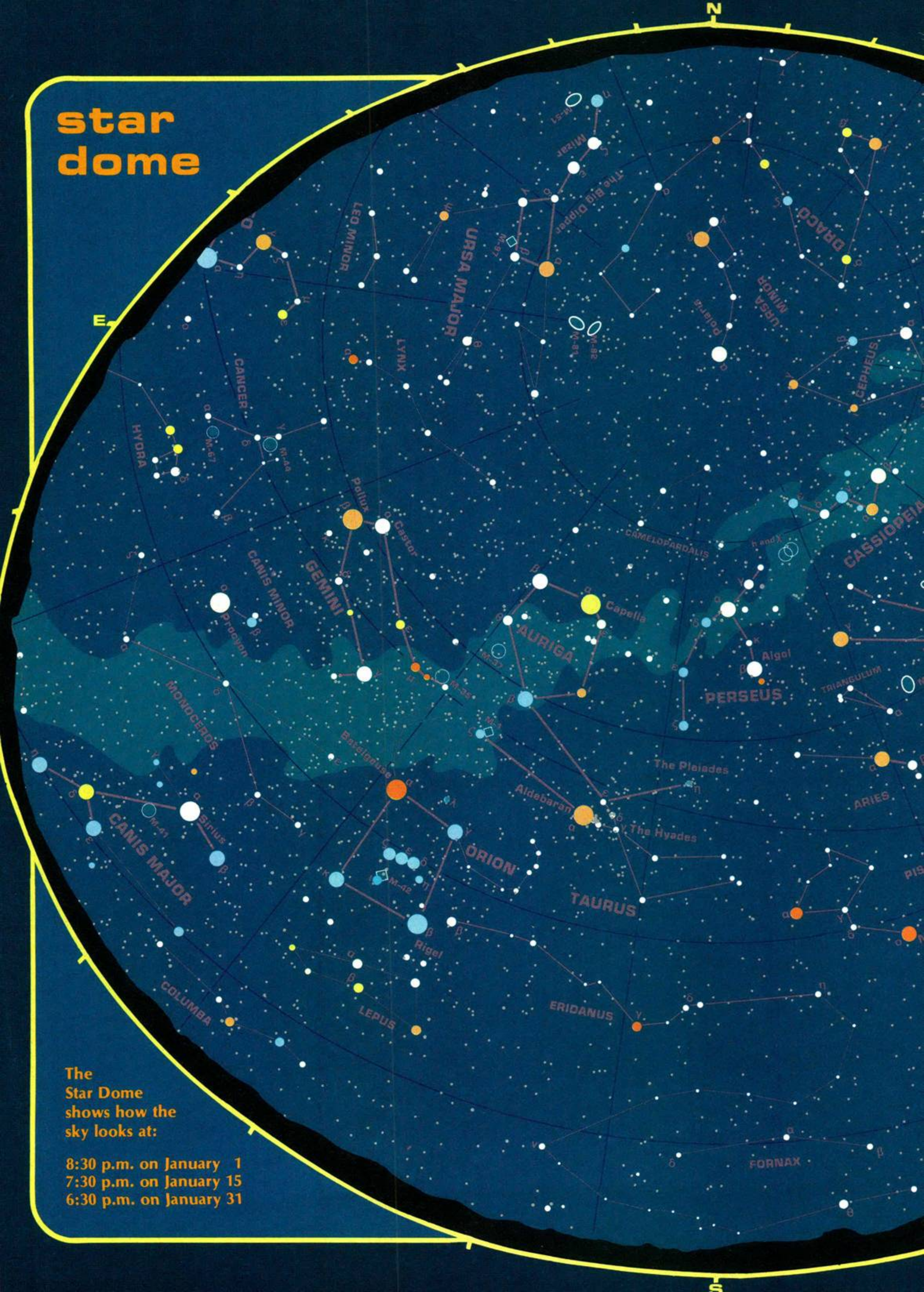
If it is too cold for a marathon observing session at your locale, you can go inside after Mars sinks and set your alarm clock a bit early (sunrise is late indeed this month). The cold will be numbing, but a good look at the morning planets is bound to be worth a few shivers. Above all, you will appreciate the sight of **Jupiter**, low in the southeast and gleaming like a jewel set in the bright head of Scorpius the scorpion.

Higher in the southeast, **Saturn** lies very close to the star Kappa Virginis. Saturn should appear distinctly brighter than Spica as it slows its eastward motion in extreme eastern Virgo. Next month, the ringed planet will come to a halt, begin retrograde motion, and start to brighten quite noticeably as it heads toward a spring opposition.

The main attraction in the pre-dawn sky, however, is the first stately cruise of Jupiter through the bright line of stars that forms the head of Scorpius. Jupiter attains an elongation from the Sun of over 60° by late January, and is a full 47° on the morning of the 10th, when it passes only 11 minutes of arc south of Beta^1 Scorpii. This is only slightly more than the maximum separation of Callisto from the planet; the view in binoculars or rich-field telescopes should be spectacular. No view, however, is likely to be better than the one available to the naked eye that beholds the loveliness of this scene in the twilight of a clear winter morning. Jupiter is predicted to shine at -1.4 and Beta Scorpii at +2.9. This is just the first

Above: Gene Hertell framed the young Moon and Venus between pine trees with a 2-second exposure on Kodacolor 100 film. He used a 200mm lens at f/3.5. Below: *A blazing aurora greets rising Gemini and Orion in this 26-second exposure through a 28mm lens at f/3.5. Dewey Vanderhoff captured it on Fuji 400 film.*

star dome


N
E
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URSA MAJOR
The Big Dipper
Mizar
M-51
M-97
M-81
M-82
LEO MINOR
LYNX
DRACO
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Polaris
CEPHEUS
CASSIOPEIA
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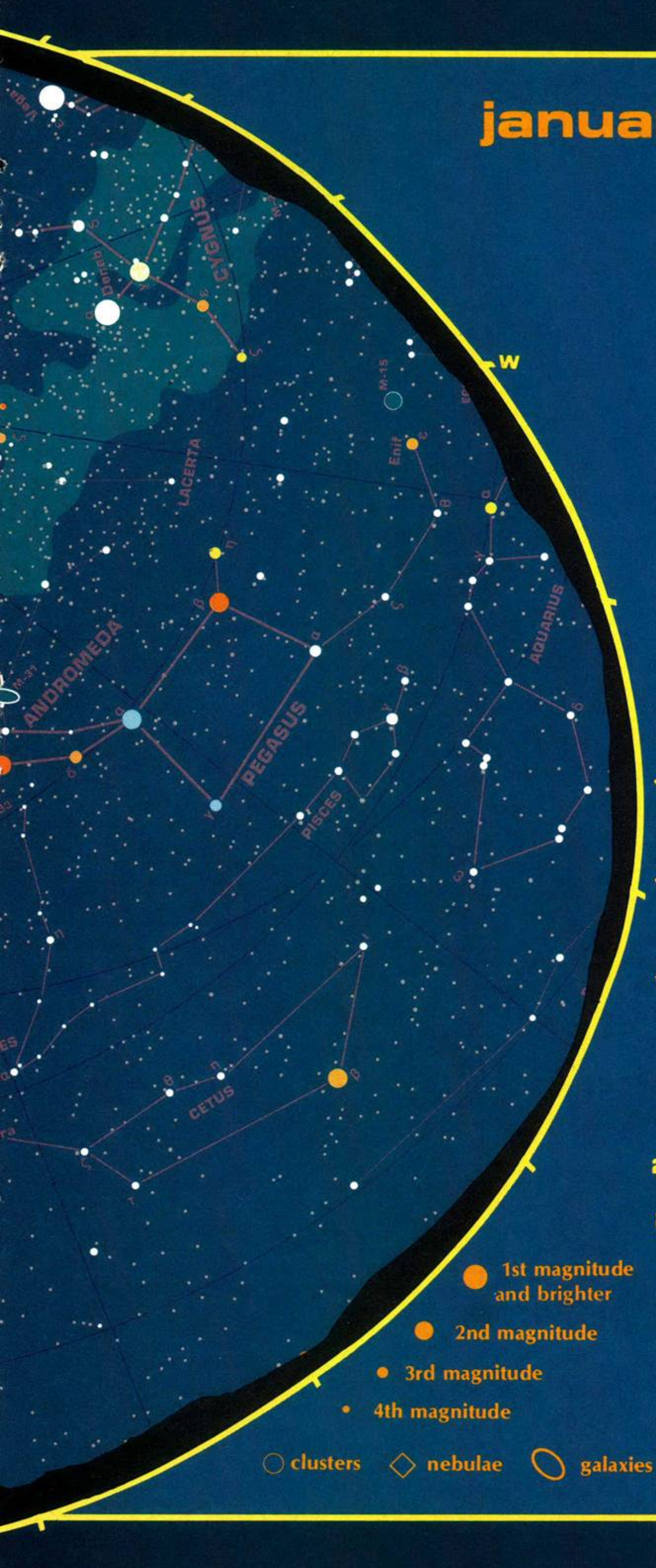
Algol
TRIANGULUM
ARIES
CANCER
M-44
M-67
HYDRA
CANIS MINOR
Procyon
GEMINI
Pollux
Castor
M-35
AURIGA
Capella
M-37
M-1
TAURUS
The Pleiades
Aldebaran
The Hyades
MONOCEROS
Betelgeuse
ORION
M-42
Rigel
CANIS MAJOR
Sirius
M-41
LEPUS
COLUMBA
ERIDANUS
FORNAX

The Star Dome shows how the sky looks at:

8:30 p.m. on January 1
7:30 p.m. on January 15
6:30 p.m. on January 31


Vega
Deneb
CYGNUS
W
M-15
Enif
LACERTA
AQUARIUS
ANDROMEDA
M-31
PEGASUS
PISCES
CETUS
1st magnitude and brighter
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

january sky almanac

2nd Earth is at perihelion: 91.04 million miles from the Sun.

3rd The early morning hours will be the best time to look for the Quadrantid meteors. Look toward the area of the sky where Bootes, Hercules, and Draco meet.

5th Last Quarter Moon is at 11:00 p.m. EST.

6th Right after sunset tonight, start looking for Mercury and Venus together, low in the west-southwestern sky.

7th The Moon will pass 2° north of Saturn in the morning sky.

9th A slimmer crescent than when it passed Saturn two days ago, the Moon will lie near Jupiter this morning.

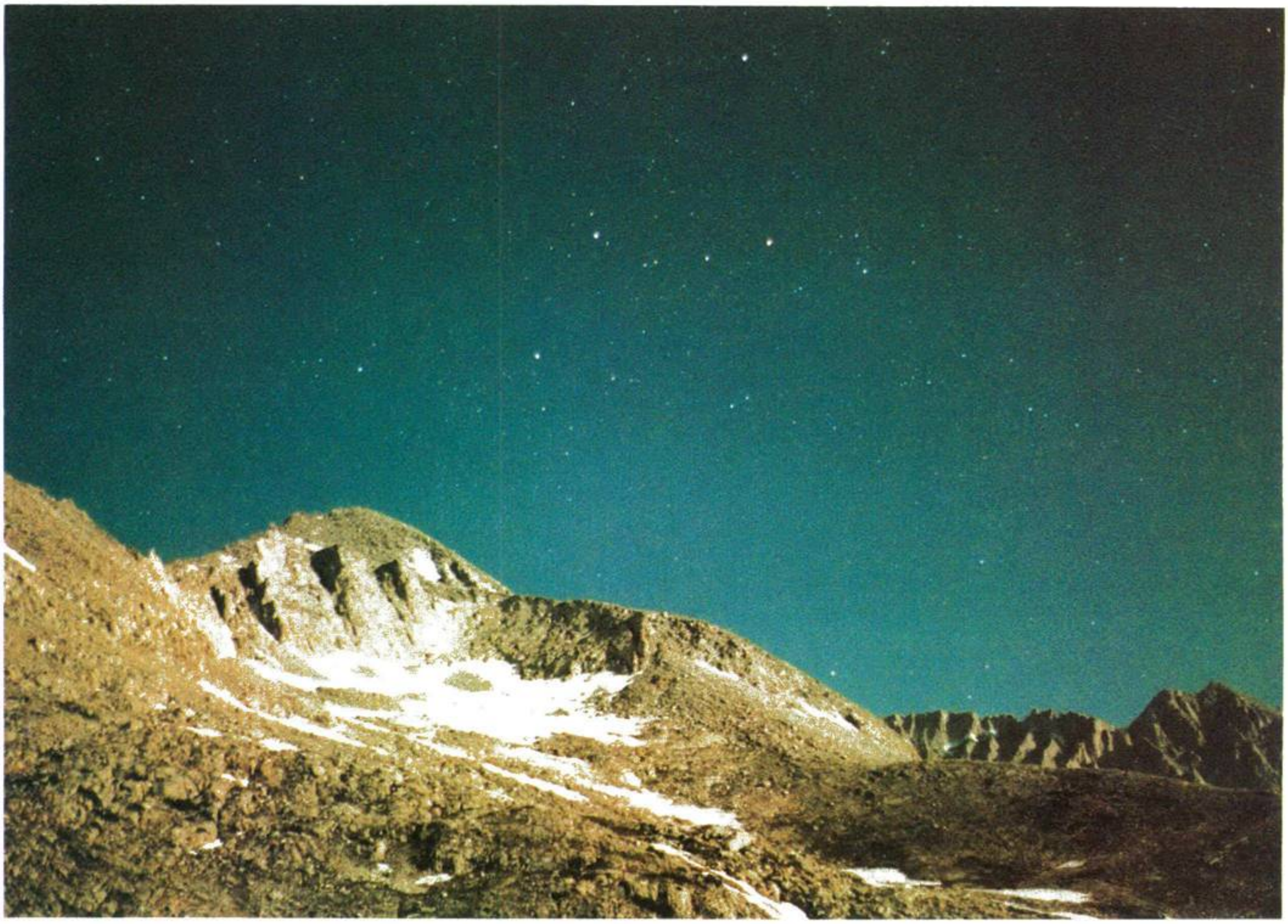
10th Tonight is about the last night to spot Mercury in the evening sky. In 10 days or so, it will reappear in the morning sky.

14th The Moon is New at 12:08 a.m. EST; at about the same time, it passes through apogee: 252,626 miles.

16th Today, Mercury passes between the Earth and Sun, shifting from the evening sky into the morning. You'll be able to catch sight of it very low in the east-southeast in a week or less. This evening, the Moon will pass 3° south of Mars.

22nd First Quarter Moon is at 12:33 a.m. EST.

28th The Moon is at perigee this morning: 221,820 miles. At 5:26 p.m. EST it will be Full.



A steady tripod and a cable release were the only accessories needed for this photo. Jim Dickerman caught Cassiopeia rising over moonlit Mount Gabb in California's Sierra Nevada Mountains, at an altitude of 11,000 feet. He used a 20-second exposure on ASA 400 film and a 50mm lens.

of three conjunctions between these objects in 1983.

Three other sets of conjunctions this year include Jupiter-Uranus, Jupiter-Antares, and Uranus-Antares. This richness of intertwined conjunctions is just one example of the fine planetary prospects that 1983 will offer. Another is the passage of Saturn by Venus when the two are a full 42° from the Sun on December 17, 1983. On that morning the pair will be only minutes of arc apart.

the starry sky

The mighty suns of **Orion** the hunter fill the long nights until threatening Scorpius rises with Jupiter in the last hours before dawn. Even novice skywatchers know radiant Orion, but there is much to learn about the stars of this brightest of all constellations, as well as his stellar neighbors.

Brightest of Orion's stars are the finest contrasting giants in the heavens — blue **Rigel** and red **Betelgeuse**. Rigel, usually the brighter of the two, shines at about magnitude +0.1 — marginally fainter than Arcturus, Vega, and Capella. (Sirius, of course, outshines them all.) Betelgeuse is variously listed as having an average brightness of +0.5 or +0.7, but it is distinctly variable. It was close to the latter figure last year, but check it out for yourself. The best comparison star is usually nearby Aldebaran, which shines at magnitude +0.9.

It is also interesting to compare the colors of Betelgeuse and Rigel with that of Aldebaran. Actually a deep orange, Betelgeuse is the reddest of any bright star — far more so than the distinctly light-orange Aldebaran. Rigel's blue is usually evident to the naked eye, but not as distinctly as that of Vega. Is this observation supported by the spectral types of the stars? Make your own study of the subtle tints of stars.

So far we have only considered the appearance of Rigel and Betelgeuse. What are these suns really like? The answer cannot be given precisely because we are still uncertain about the distances to these (and many other) stars. Many books still report the distance to Betelgeuse as about 300 light-years, Rigel somewhat more than 500. More recent figures give their distances as about 520 and 900 light-years, respectively. Rigel is obviously a far more luminous star than Betelgeuse — in fact, one of the most luminous visible to the naked eye. On the other hand, Betelgeuse is one of the largest stars observable; at maximum size in its pulsation cycle it could fill the solar system almost out to the orbit of Jupiter. As in all red giants, however, the outer layers of Betelgeuse are extremely tenuous. So although Betelgeuse is perhaps 20 times more massive than the Sun, it is much less massive than Rigel, which is many times smaller than Betelgeuse.

The table on page 42 lists estimated distances and luminosities of the most conspicuous stars in Orion. Most noticeable of all, of course, are **Alnilam**, **Alnitak**, and **Mintaka**, the stars of Orion's Belt. That well-known trio not only lies across the Hunter's middle, they lie across the middle of the starry sphere, the celestial equator. Mintaka, the northernmost of the Belt stars, is located less than half a degree south of the celestial equator. South of the Belt are the three stars of Orion's Sword, the central one of which glows with the fabulous wreath of the Great Orion Nebula — a deep-sky object that is a fine sight even in binoculars.

Looming over Orion is the

stampeding bull, **Taurus**. His eye is **Aldebaran**, his face the **Hyades** open star cluster. At his shoulder are the sparkling **Pleiades**, supposedly mourning for their missing sister, the Lost Pleiad. His horns are pointed with the bright star **Beta Tauri**, or El Nath ("the butting"), and the much dimmer **Zeta Tauri**. This latter star is probably the most notable of all for which we have no proper name — unless we resort to ancient Sumerian! Zeta Tauri deserves attention most especially because of its proximity to the famous Crab Nebula. In 1054 A.D., Zeta was bathed in the brilliant light of the supernova that formed the nebula.

Perched atop Beta Tauri, right above Orion in this very interesting slice of sky, is **Auriga** the charioteer. Brilliant Capella is always this constellation's major attraction for naked-eye viewers — except for a couple of times out of a lifetime: this month, **Epsilon Aurigae** begins the total phase of a mysterious eclipse for the first time since 1956.

Epsilon is the northernmost of the three **Kids**, usually a little brighter than **Eta Aurigae**. But this month, and during the entire year-long total eclipse, it is similar to **Zeta**, the third Kid. Astronomers believe that Epsilon Aurigae A is a superluminous star, one of the farthest points of light visible to the naked eye at a distance of around 2000 light-years. But what is the object that eclipses it? A dim red giant (or infrared giant) star, far larger than even Betelgeuse? Or perhaps a cloud or ring of material surrounding a small, dim companion? Perhaps studies of the present eclipse will provide some of the answers.

Following Auriga across the heavens in the highest tier of the winter constellations is **Gemini** the twins and its luminaries Castor and Pollux. Test your ability to estimate stellar brightness with these stars. Pollux is obviously the brighter, but what is the magnitude difference?

We can continue the giant curve of bright stars near Orion southward from Pollux to Procyon, the *lucida* (brightest star) of Canis Minor, the little dog. From this star our gaze is drawn to the final first magnitude star of the winter constellations, the very lucida of the entire starry sky: **Sirius**, the Dog Star of Canis Major, the great dog. January is the month of the Hunter's mid-evening culmination, but next month Sirius reaches this position and we will continue the hunt of Orion and his starry dogs.

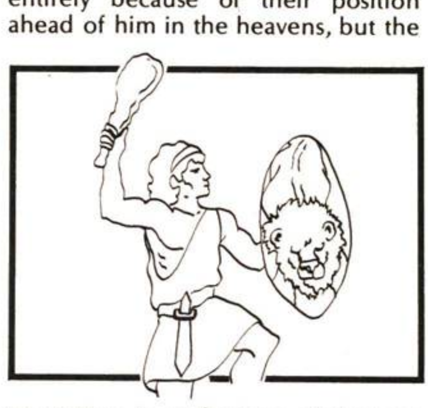
skylore

Popular collections of mythology seldom tell as much about the story of Orion as many starwatchers would like to know. There are, of course, advantages to telling a simple version of the story: incorporating variants and additional details interrupts the narrative flow. A basic version of the Orion tale appeared in this column two years ago (January 1981). But there is a great deal more to say about this mythical figure that is not found in most books on mythology.

One intriguing example is provided by Orion's wife and daughters. They are not central to the story of his greatest adventures (or misadventures), but they are notable in their own right and even have some special astronomical significance.

Orion's wife was Side — a name whose meaning will be guessed by anyone who knows what sidereal time is. She died young — or rather was taken to Tartarus, the nethermost region of the underworld — because she enraged Hera by claiming that she was more beautiful than that goddess.

After Side, Orion had many love interests. Among them were Merope (not the Pleiad of that name), who is sometimes called Aero; Eos, goddess of the dawn; the Pleiades (this may be entirely because of their position ahead of him in the heavens, but the reputation is at least as ancient as Hesiod); Artemis, goddess of the hunt; and Opis or Ursis, a priestess of Artemis who may have been a Hyperborean (see the story of Perseus in the October and November 1982 issues).



Most of these affairs are alluded to in popular collections of mythology, but a story that is seldom mentioned concerns the daughters of Orion. One of them was Menodice, the mother of Hylas, whose probable father Theiodamas was killed by Hercules. The strongman thereafter adopted Hylas as his page and dear friend. Orion's other daughters (by Side?) were Menippe and Metioche, who were called the Coronides. The two were said to be extremely beautiful and actually taught wise Athena the art of weaving. They sacrificed themselves in order to save the city of Orchomenus from a plague, and as a point of special interest to astronomical people, were transformed into comets!

What about Orion's birth and death? His father was almost always said to be Poseidon (whence came, some say, his ability to walk over the waves of the sea). His mother was Euryale — not the hideous Gorgon sister of Medusa, but another Euryale, the daughter of King Minos of Crete. Orion's most famous aunt was Ariadne, the maiden who helped Theseus. Abandoned by that Minotaur-killing hero, she was received by Dionysus, who married her and gave her the queenly ornament that now appears in the heavens as Corona Borealis, the Northern Crown.

There is a story that Orion's true father was a man named Hyrieus. One version tells how Zeus, Poseidon, and Hermes, disguised as mortal wayfarers, visited Hyrieus, the king of Hyria in Boeotia. The king was so hospitable and kind to his guests that they revealed their identities and asked him to name his wish. When Hyrieus asked for a son, the three gods responded by urinating on a heifer hide and burying it. Nine months later Orion emerged from the ground — surely one of the strangest births in mythology.

The explanation for this bizarre legend is probably in the claim that Orion was a son of mother Earth and in the similarity, in Greek as well as English, of the words urine and Orion. An earlier Greek name, Urion, was even closer. Another version of Orion's birth dispenses with Earth and says that Hyrieus was not a king, but rather a humble bee-keeper and farmer who, in his old age, regretted his decision to have no children. His guests, Zeus and Hermes, instructed him to urinate on a bull's hide and bury it in his wife's grave. Orion, son of Hyrieus, was born from the ground nine months later.

Orion's death, by either the scorpion sent by Hera or an unknowing Artemis, has been discussed in the January 1981 issue. But I did not mention then that Orion may have been resurrected from one of these deaths. The healer who returned him to life was none other than Asklepios (Latin Aesculapius), who is possibly represented in a constellation halfway around the sky from Orion, Ophiuchus. Some say that Asklepios raised several people from the dead, but others claim that the resurrection of Orion troubled Hades and made it necessary for Zeus to strike both Orion and his healer dead with a thunderbolt.

Last of all, we may wonder about the true source and meaning of the name Orion. Is it ultimately derived from the Mesopotamian Uru-anna, the Light of the Heaven? Robert Graves translates Orion as "dweller on the mountain," but perhaps we may understand this as dweller in a high place — a fitting title for the heavens' most brilliant constellation.

ASTRONOMY REVIEWS

Kodak Ektaflex Processor Model 8
Price: $75 to $100
Print cost: $2 to $3 per 8x10 print

There have been many articles published in the amateur photo magazines on how to use the Ektaflex processor. Instead of repeating the same material, I'd like to look at the process from the amateur astrophotographer's viewpoint.

First of all, this is probably the most thoroughly-documented consumer product Eastman Kodak has ever produced. You get a book on how to assemble the processor, and the book is complicated — but it makes the assembly utter simplicity. You also get several booklets on how to make prints, although they don't cover everything you need to know. Information on the vital numbers — exposure and processing time — is packed with the film.

Be careful when you unpack the instructions from the film package: the information you need is on two sheets. And save the postcards packed with your processor — send them in and Kodak will mail back some nifty wall charts to help you get good prints with the least effort.

Actually, the whole process couldn't get much easier. In the past, I've made color prints with daylight drums, Kodak's rotary processor, basket lines, and even sweated through a dye-transfer print — once. By comparison, this is a snap.

The Ektaflex process uses two sheets of material for each print. You expose a film in your enlarger as usual. After briefly soaking it in an activating solution, you turn a crank on the processor which laminates the film to a receiver paper. After a few minutes' wait, you peel the sheets apart as you would an instant print. This simplicity is the key to the versatility of the process.

You have the choice of two films: one yields prints from negatives, the other makes prints from slides. One very nice feature is that you can switch back and forth between printing slides or negatives all evening long just by changing to a different filter pack and exposure time — although it is best to do all your slides at one time and then switch to negatives to avoid getting your numbers all mixed up.

I used a Beseler enlarger with a Vivek voltage stabilizer. The stabilizer runs the enlarger lamp at 90 volts, which shifts its light toward the red. This works out very well, as I needed only 10 M of filter pack to print most of the astro slides I tried. Twenty seconds' exposure at f/5.6 was enough for most 8x10s.

It's almost impossible to waste a sheet of film by making a mistake during exposure. The film is notched in the upper right corner of each sheet when the emulsion is facing you — just like other sheet films. Even if you were to fumble-finger a sheet into the easel the wrong way up, it's no big deal. Since the film backing is an opaque black, you can tell immediately if you have put it in wrong. Then you simply turn off the enlarger and flip the film — it hasn't been hurt a bit. Try *that* on your regular printing papers!

Loading and operating the processor is also a snap. Kodak suggests you squander a sheet of film and paper on a dry run in room light for practice. Baloney! The film is too expensive. If you want practice, use some old single-weight prints for the film and receiver paper — and remember, "dry run" means leave the chemicals out.

I found that making prints from slides was definitely the easier job. Positive material is always less contrasty than negative film and so you're less likely to overcorrect your filtering and exposures. My second print from a slide was a "keeper."

By the time you read this, Kodak will have released a transparent receiver sheet material for making overhead transparencies. I managed to wangle some pre-production samples to try. My first print was superb. The material will work like any other Ektaflex receiver sheet, provided you allow for the following changes: expose negatives one-half stop more to make it denser and expose slides one stop less. To prevent fogging, put the laminated film and receiver in a light-proof box until it's time to peel them apart.

I expect the overhead transparency will become a great hit with those who give lectures frequently. They also make good graphs using litho masters and colored gels. And the quality is much better than the overheads Xerox produces.

Additional pluses: Ektaflex paper and film keep well. You don't have to plan a blitz printing session to use up your supplies before the chemicals go weird on you. There's no temperature control or chemical mixing to worry over. You can set up and run a couple of prints in half an hour or less.

The minuses: the big one here is cost. An 8x10 will run $2 to $3 in materials, depending on where you get your supplies and whether you're printing from slides or negatives.

Second, your finished prints, while expected to be as stable as any other color material, must *not* be stored with other types of color prints. I've heard that residual chemicals *in* Ektaflex prints can react adversely with the dyes in other prints.

Third, you have to work carefully and watch those splashes. The activator solution is strongly alkaline, so pour it into the *processor carefully*. I would like to see an anti-drip ring on the activator bottles: if you pour too slowly, the activator dribbles down the side of the bottle and makes a mess. If you pour too fast, it splashes.

You'll need a screwdriver to open and close the drain valve on the processor. Why didn't Kodak provide a handle or knob?

I suggest that any astronomical user make a first print from a portrait or landscape shot to zero in on exposure and filtration. Then a "ganged" contact sheet of a couple of dozen negs or slides will help you establish the proper exposure and filtration requirements.

In summary, I love it! The shortcomings do not outweigh the many advantages and conveniences. Yes indeed, it does cost more per shot than other materials, but I suspect you'll waste less from mistakes and outdated chemicals. *James R. Bailey.*

Astronomical Photometry
Arne Henden and Ronald Kaitchuck
392 pages, hardbound, $29.95
Van Nostrand Reinhold (1982)

In many ways, the practice of astronomical photometry is still an art, heavily tempered by individual experience. How-to books and even papers in the professional literature are few, and much of the knowledge is handed down from one practitioner to another. Although its authors indicate that they have written a book aimed at amateurs, *Astronomical Photometry* may be read with profit by students and researchers at all levels.

Many variations exist in astronomical photometer construction and in data handling; each observer has a favorite technique. The authors expound their methods for undertaking a successful observing program; while these methods may not prove optimum for everyone, they do provide a starting place for the neophyte.

One of the book's most valuable aspects is the excellent set of references provided at the end of each chapter. They not only point the reader toward more complete discussions of certain topics in the professional literature, but also list the names and addresses of parts suppliers for constructing equipment.

The beginning chapter, appropriately enough, tells about the history of astronomical photometry, and then stresses some of the important prerequisites for doing photometry: for example, to acquire data successfully, a telescope has to have a good drive and a solid mounting. Next, the authors discuss the type of light detector most useful to amateur observers, and give initial definitions of instrumental magnitudes and color indices. They also provide an

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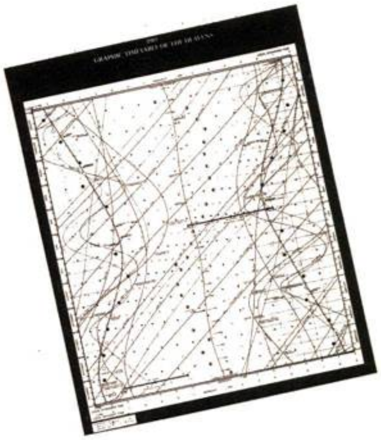

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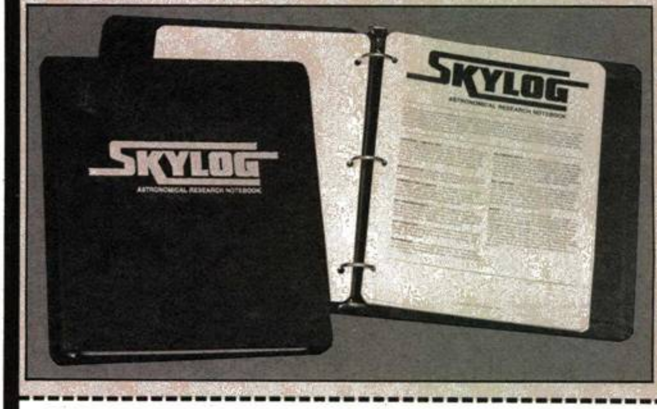
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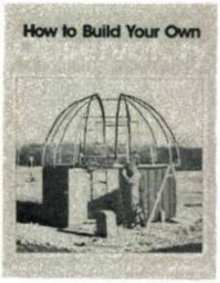

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introduction to the concept of extinction corrections and to the need for transforming one's data onto a standard photometric system.

Chapters 2 through 5 introduce different photometric systems, error analysis, data reduction, and the calculation of quantities needed to evaluate data. The authors chose the wide-band UBV photometric system in their illustrative examples throughout the book, since it is the most commonly-used photometric system. Further, the equipment necessary to define and utilize the system is readily available and not too expensive. The authors recommend the technique of differential photometry as a way for newcomers to begin acquiring photometric data with a minimum of pitfalls.

The method for calculating a best value from data is illustrated in chapter 3 where the reader learns how to determine just how good such "best values" really are. The authors tackle the question of which data, if any, are to be rejected, and how to use the method of least squares in fitting lines to observational data. Here, and in many instances in the book, examples are worked out so the reader can check his understanding of the concept.

How does an observer go about reducing photometric data? The answers are given in chapter 4. The authors provide recipes for the determination of the dead-time correction, atmospheric extinction, and for the calculation of transformation relations between instrumental and standard photometric systems. Material in chapter 5 shows the observer how to precess coordinates, how to predict when an object will be visible, and how to calculate time and date quantities. Again, worked-out examples are provided.

Chapters 6 to 8 deal with the construction of a photometer and its associated electronics. The authors explain and illustrate the relative positioning of the various photometer components. They give practical tips on the mounting of filters, the construction of diaphragms, and the selection of photomultipliers, as well as sketches of the electronic circuitry needed to make the photometer operational.

The penultimate chapter lays out practical observing techniques. An observer needs a chart to ensure proper identification of the object to be studied, so the book lists various maps and charts of the sky which have proven to be of use to observers through the years, and tells where to buy them. It also gives hints for the selection of comparison stars needed to undertake variable star investigations. The chapter concludes with sections telling what to do at the telescope, how to take sky background readings (and why they're important), and how to prepare for work before going out to the telescope. This fussiness is not just whimsical: being prepared ensures not only efficiency, but enhances the probability of useful data.

The final chapter lists examples of worthwhile photoelectric photometry projects. The entire field of variable star research has been, and will continue to be, a fertile area for amateur and professional astronomers alike. The book's lists of representative variable stars from several different classes provide rich fields of study for the interested observer.

The authors end the book with 15 appendices that fill 100 pages. Here are lists of extinction stars and standard stars, as well as charts for several standard star fields. The authors work out examples of calculating extinction and transformation coefficients. One appendix provides several FORTRAN subroutines useful in data reductions for those who have access to a computer.

This is a good and useful book, embodying many years of practical experience and thought. Would-be photometricists should read the book thoroughly before they venture out to the telescope, or ideally before they undertake the construction of a photometer. Stellar photometry is a very pleasant experience — not only is it fun to do but it also collects important data useful to a variety of leading astronomical problems. I trust many will enjoy the book and find it as useful as I have. *Arlo U. Landolt.*

Wolf-Rayet Stars: Observations, Physics, Evolution

C.W.H. De Loore and A.J. Willis, eds.
618 pages, papercover, $34.50
D. Reidel (1982)

Wolf-Rayet stars are very luminous, very hot stars whose spectra have broad emission lines presumed to originate from material continually ejected from the star by high-velocity stellar winds. They may be the exposed helium cores of stars that were once hydrogen-burning main-sequence suns. This volume contains 80 papers and 10 invited reviews presented at the IAU symposium held in September 1981. The papers concentrate on new observational results of this peculiar class of stars in all wavelength regions. Chemical composition, mass loss rates, and observations of WR stars in the Milky Way, the Magellanic Clouds, and M-31 are also discussed.

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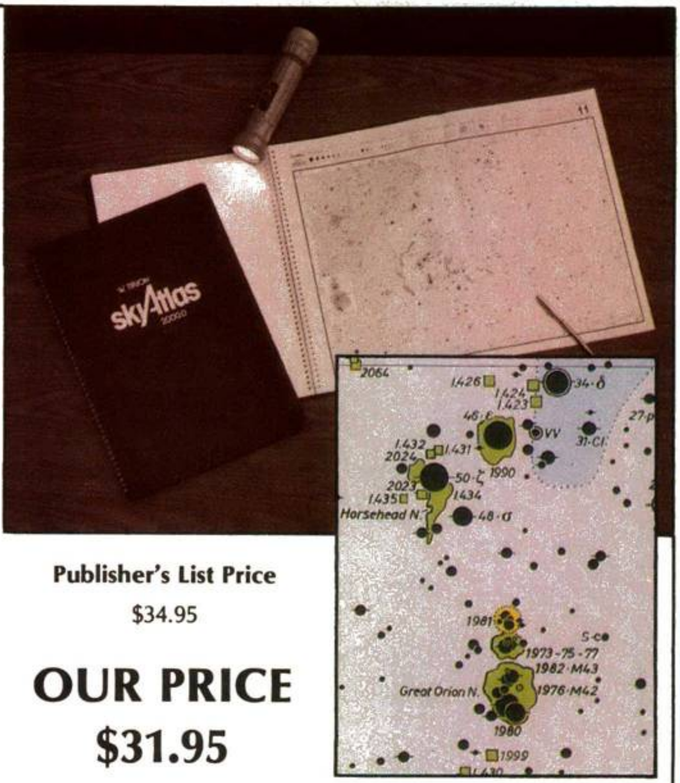
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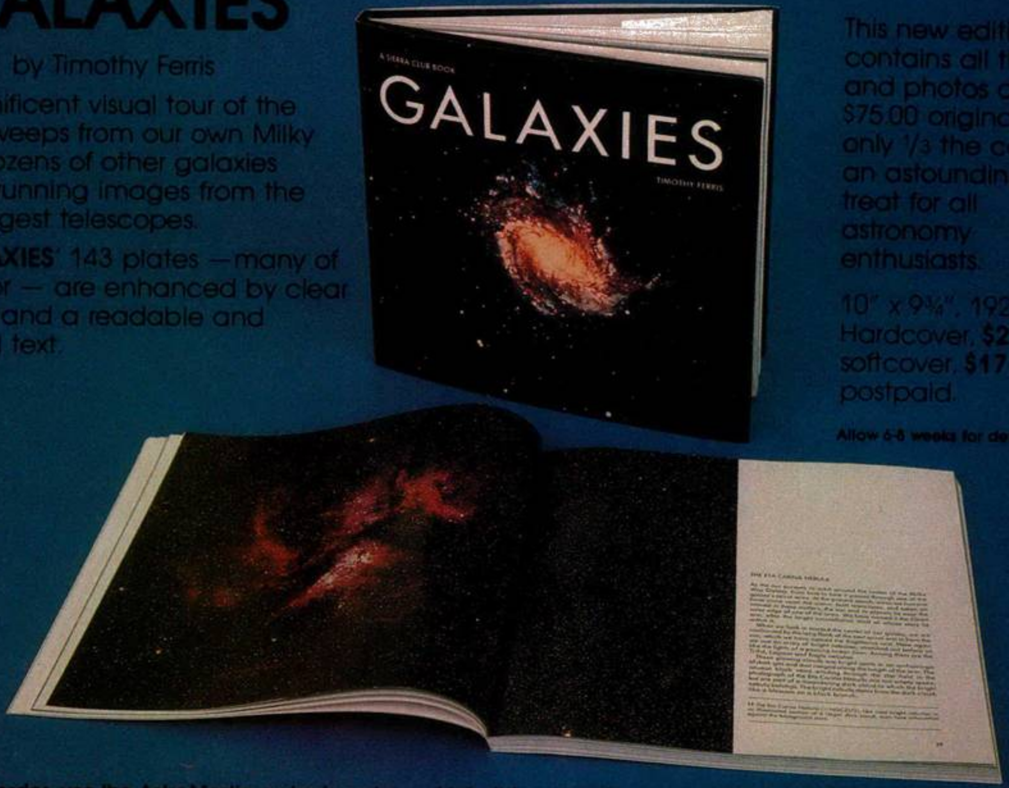
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equipment
atlas

a mini-observatory for your backyard

by
Nicholas Henderson

bill of materials

8 2x4s, 8′ long
2 sheets 4′x8′x¼″ exterior plywood
2 lbs. 10d nails
 (“Ardox” or “Stay Fast”)
I lb. 6d nails (finish)
4 3″ hinges
2 door hasps
2 4″ handles
2 1x2 furring strips 8′ long
4 8″ diameter lawnmower wheels
6′ of ½″ threaded steel rod
 (make sure this fits your wheels)
20 ½″ nuts, to fit threaded rod
16 washers, to fit threaded rod
1 small box carpet tacks
⅓ of a square of shingles
½ lb. roofing nails
1 quart primer paint
2 quarts oil-based exterior paint
10 ft. of weather stripping
2 or 3 tubes of latex caulk
8 bags of ready-mix concrete
 (more if pad is larger)
4 anchor eye-bolts (optional)
4 washers to fit eye-bolts (optional)
8 nuts to fit eyebolts (optional)
4 latches to fit eye-bolts (optional)
3′ PVC electrical conduit
1 right-angle conduit section
1 outdoor electrical outlet
2 conduit connectors
1 connector from conduit to box
small amount of PVC cement
underground-burial electrical cable
 (length depends on site)
extra-length pier (see text)

“Easy Steps to Perfect Polar Alignment” (ASTRONOMY, August 1982) started me thinking about how I use my telescope — or rather, how I *don’t* use it. Like many observers who buy a first telescope, I got the largest-aperture instrument I could afford, an excellent 8-inch Newtonian on a German equatorial mount. But in buying the scope, I also bought a weight problem — that fine equatorial mount was infernally heavy.

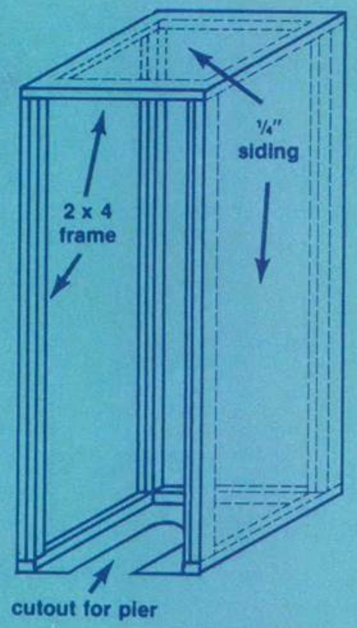
After an initial period of excited use, I began to dread hauling the big, heavy mounting out and spending half the evening fooling with Allen wrenches and other hand tools, getting it into adjustment. To me, observing means looking through an eyepiece — and I wasn’t doing enough of it.

In response, I bought a 4-inch catadioptric scope, which was certainly a lot easier to set up and use — though I did miss the 8-incher’s aperture. Then it hit me: Why not make a simple little structure that would house the mounting? Carrying the tube in and out of the house was no problem, and once I got the mount properly aligned, I could be observing in minutes, instead of hours. My “mini-observatory” was the happy result.

Now if you’re as ham-fisted as I am when it comes to home handywork, you might be thinking that even this scaled-down job is beyond you. Take heart — it isn’t! I’m no carpenter, as anyone who has seen my “jack-leg” household repairs could attest to, but I still polished off the entire project in about 40 hours. The cost was low, too, as the bill of materials ran to about $200.

My backyard faces south, and I have a good view of the sky in that direction. Accordingly, I designed the mini-observatory to roll off toward the north. I made no provision for tying the building down; the structure weighs about 150 to 200 pounds, and the winds where I live (west-central North Carolina) have given me no problems. However, there are two ways of securing it which those who live where the winds freely howl may want to use. I’ve detailed them in the construction part below.

The bill of materials (see box) and plans in this article are guidelines, not gospel. The size of your mounting will determine the exact dimensions of your mini-observatory, but adjusting the plans to fit is not difficult since the construction is simple and straightforward.



Some general hints: Where I say to nail something together, use carpenter’s glue (Elmer’s “yellow” is fine) as well for an extra-tight joint. Also, before you cut a piece of wood, measure where it goes first. As you assemble the structure, little errors will creep in, and following the “correct” dimensions listed may produce misfit parts in your structure.

Framing Up the Observatory

To begin, cut eight sections of 2x4 lumber into pieces 45″ long. Then nail the sections together side to side in pairs, after making sure their ends are even. These four will become your corner posts.

Next, cut the pieces for the top and bottom frame. The top frame consists of four pieces of 2x4, each cut at a 45° angle on both ends. These pieces measure 24″ along their "outside" edge. The bottom frame consists of three pieces of 2x4. Two are square on one end and cut at a 45° angle at the other; the third has both ends cut at a 45° angle. Once again, you want to make them come out 24″ long on the outside edge.

Next, join the pieces with glue and drive nails through the 45° joints, being careful not to split the wood. At this point, you'll find the help of another person very useful. While your assistant holds one of the corner posts upright, nail the top frame onto it, using 10d (i.e., "ten-penny") nails. The "Ardox" or "Stay Fast" type is best: they have little grooves or a spiral and don't pull out. Continue in this fashion until you have attached all four corner posts. Then turn the whole thing over and nail on the bottom frame. Throughout the process, keep checking all the corners to see that they are reasonably square.

Installing the Plywood Siding

First, cut out the two sides (24″x48″) and the back (24½″x48″) from ¼″ plywood. Then cut out the top and bottom pieces (24″x24″). Next, choose one of the square pieces as the bottom and cut the arch-shaped hole in it. This hole allows the completed building to fit around the pier of your mounting. Then attach the top, sides, back, and bottom to the frame, using 10d nails and carpenter's glue. (Don't spare the nails.) When complete, liberally caulk inside where the wood sections meet.

Attaching the Wheels

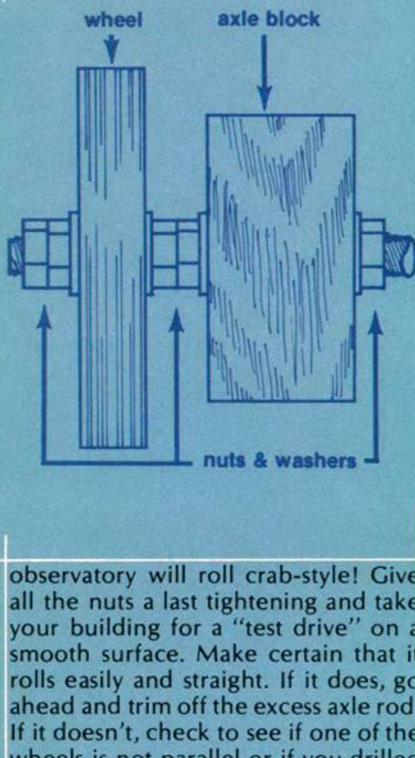
The wheels come next. First, cut four 6″ pieces of 2x4 — these will become the axle blocks. Using a ½″ drill, bore a hole through the center of the 1½″x6″ face of the block. Take some pains to ensure that the hole is perpendicular to the face of the axle block.

Next, use a hack saw to cut the threaded rod into one 36″ long and two 18″ long pieces — these are the axles. It's a good idea to thread a nut onto the rod past the place where you are cutting, then back the nut off over the cut when you have finished. This will restore any threads you damage in the cutting.

Now take one of the 18″ axles and fit it through the axle block, leaving most of its length sticking out on one side. Put a washer and nut on the short side of the axle block. Then put a washer and a nut on the other side and tighten the nuts securely. Thread on another nut, clear up to the nut already in place on the long side, then a washer, then the wheel, then another washer and finally two more nuts. Tighten the outermost two nuts onto each other, but be sure the wheel can still turn freely. Repeat the process with the other 18″ axle. Don't worry about the excess axle rod; we'll trim it down later.

Now turn the building upside down and assemble the 36″ axle in place in the same way that you did the short axles. This will give you a wheel assembly at each end of the 36″ axle. When you have the wheels and axle blocks positioned correctly on the bottom of the observatory, tighten up the nuts to hold all the parts from sliding back and forth on the axle.

When you nail the completed wheel assemblies onto the bottom of the building, be sure to install the wheels as nearly parallel as possible or your observatory will roll crab-style! Give all the nuts a last tightening and take your building for a "test drive" on a smooth surface. Make certain that it rolls easily and straight. If it does, go ahead and trim off the excess axle rod. If it doesn't, check to see if one of the wheels is not parallel or if you drilled an axle hole crookedly, and correct.



On Goes the Roof

The basic building is complete, but it needs a roof. A pitched one is best, since flat roofs tend to accumulate water. To make the rafters, cut four pieces of 2x4 with 45° angles on each end, $17\frac{5}{16}$″ along the outside edge. Glue and nail two of the rafters together, 45° angle to 45° angle, then nail this unit onto the top of the observatory across the front. Next, repeat the process with the other two pieces across the back of the structure.

Cut four stringers out of 2x4, with square ends, each 19¼″ long. Do this carefully, measuring from the inside of the front rafter to the inside of the back rafter. Fit the stringers between the rafters and nail them in place, nailing through the rafters into the stringers.

Next are the two end covers. For each, take the corner of a sheet of plywood and measure 18″ from the corner along one side and mark the spot, then measure 18″ from the same corner down the adjacent side and mark that spot, too. With a straightedge, draw a line between the two marks and cut along that line. If your assistant holds the piece as you cut, it won't droop and splinter. Next, lay out the roof pieces. One should be 24½″x18″ and the other should be 24½″x18¼″. (The extra is so the pieces will overlap at the gable.)

Nail the two end pieces onto the rafters, using the 6d nails. Next, place the 24½″x18″ roof piece along the sides of the rafters and bring it up until it is even with the top of each rafter. Hold it lightly with a few nails driven a short distance into the rafters. Repeat the fitting process with the other piece, making sure to overlap the edges at the top. When they fit snugly, drive the nails the rest of the way into the rafters and use plenty more.

Hanging the Door

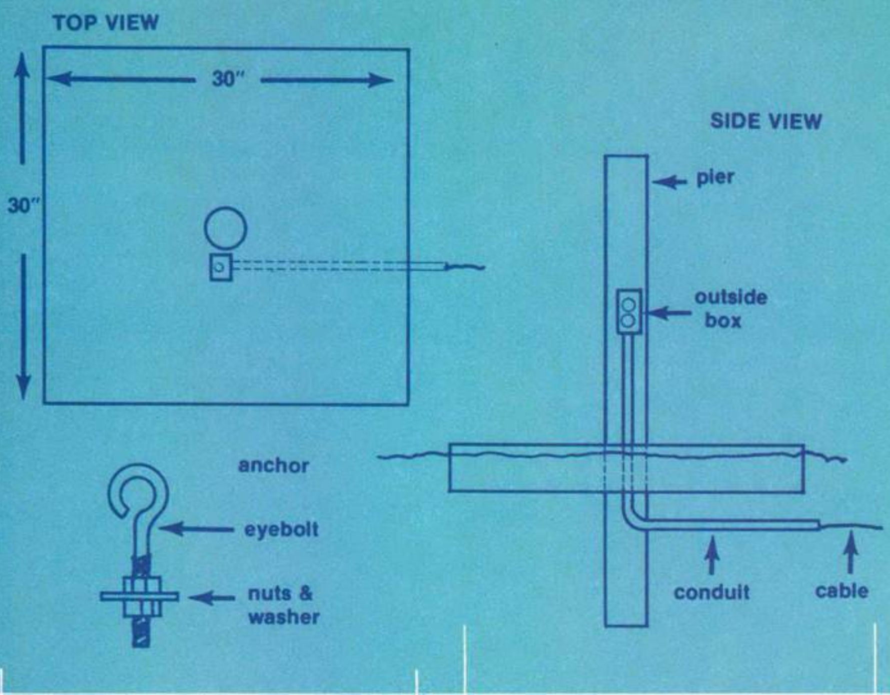
First, cut out two pieces of 1x2 lumber 44¾″ long and two pieces 24½″ long. Nail the pieces together using 6d nails to form the door frame; be careful not to split the wood. Cut the door panel out of plywood, making it the size of the outside dimensions of the door frame. Apply glue to the frame where the door panel goes and nail the panel to the frame with carpet tacks. When dry, caulk the inside.

Next, screw the hinges to the side of the door frame. And finally, screw the hinges onto the side of the observatory, so that the door swings open and closed. Get your assistant to hold the door at the right height.

Finishing Touches

To help keep the rain out, weatherstrip the door facing, then attach the two door hasps, positioning them so that when they are engaged, the door is pulled tightly against the weatherstripping. Next, attach sections of 1x2 trim around the top of the observatory, where the roof overhangs the sides and back. Caulk this carefully so that rain will not run back in off the ends of the roof. Then apply the shingles with roofing nails. Finally, run a piece of 1x2 horizontally across the back of the observatory, somewhat more than half way down the back. This is the attachment for a handle to pull it with.

Now you are ready to paint. First apply a coat of primer, and after the primer has completely dried, apply two or more coats of waterproof finish paint. Oil-based paint, though messier to use, will last longer than latex.



Finally, screw on the two handles, one to the trim on the back of the observatory and the other to the strip you put on the back.

Installing the Mounting

At this point, the building is finished, though you still need to construct the pier and pad.

A well-installed mounting has a pier that is anchored to the ground. My telescope has its equatorial head at the top of a cylindrical metal column. I was able to obtain an extra-long section of this column from the manufacturer. If your telescope is this type, but your manufacturer can't or won't sell an extra-length column, get a piece of commercially-available pipe in the right diameter, 2 feet longer than your regular pier, from a plumbing or builders' supply store.

Having obtained the long pier, dig a trench about 6″ deep from the site of your observatory to the nearest source of electricity. Lay in the trench a length of underground direct-burial electrical cable long enough to run from the source to the pad with about 6′ left over.

Next, dig out the area where the pad will go. I made mine 30″x30″ — if you want yours larger, keep it as small as you can, because a large pad acts as a heat trap that can ruin good seeing for hours after sunset. Dig the area for the pad about 4″ deep and a few inches larger on a side than the pad will be. Next, frame the hole with 2x4s to make a form for the concrete. Don't nail the form together, but hold it in place with stakes driven into the ground on the outside of the frame.

Dig a hole in the center of the frame (a post-hole digger is best), deep enough that the pier will extend from the bottom of the hole to the height you want it to have in use. Pack the excess dirt in around the pier, tamping it tightly. As you go, check the pier to make sure it's vertical.

Next, measure from the pier to the edge of the frame, and cut a section of conduit about 6″ longer than this. Thread the 6′ of excess wire through the conduit; one end of the conduit should end up near the pier. Run the right-angle section of conduit over the wire and down to the section already in place. Slip a conduit connector over the wire and down to the right-angle section. Next, determine the distance from the end of the right-angle section to the height you want your outlet (I chose 12″). Cut a piece of conduit this length and slip the section over the wire and secure it to the right-angle section with another connector. Check the arrangement carefully, and when everything is in place, glue the pieces together using PVC cement.

Next, screw the connector for the electrical box into the hole in the bottom of the box, then run this assembly over your wire and glue it in place with the cement. Leave the excess wire hanging out of the box. Make certain that the end of the conduit extends beyond the form a little way, and tape the box end (temporarily) to the pier. Bury the cable by filling in the trench.

When you mix the concrete for the pad, you may want to do it one bag at a time — if you misjudge how much to buy, you'll cut down on the waste. I mixed mine in a plastic mortar box purchased for this purpose, but an old wheelbarrow will work fine.

As you finish mixing each load of concrete, dump it into the form and spread it around with a shovel, working it into the crevasses. When the form is full of concrete, smooth the surface with a trowel or a straight-edged piece of board. To make your mounting really steady, fill the hollow pier with concrete, too.

This is the point to incorporate tie-downs for the shelter, if you want them. The sturdiest way is to use anchor eye-bolts. Placing them so that they stick up above the surface of the concrete is easy to do, though you'll probably be tripping over them in the dark for years to come. If the bolts tend to sink or flop over in the wet concrete, fashion a little jig out of scrap lumber to hold them upright.

To avoid stubbing your feet on the bolts, try recessing them into the concrete. Cut off the tops of four empty aerosol spray cans and punch out the nozzle. Insert the eye-bolt through the nozzle hole with the eye "inside." Then push these assemblies down into the wet concrete so that the top of the can forms a cup with the eye of the bolt below the surface of the concrete. The bolts can go anywhere on the pad you like, but placing them inside the housing helps make the structure a little more thief-resistant.

Depending on how bad the winds are in your location, the tie-downs can be steel latches that slip through the eye-bolt, a set of stout bungee-cords, or even ordinary rope.

A simpler approach is for you and your assistant to pick up the observatory and hold it in place over the pad. Together, you lower it gently until the wheels sink about an inch into the wet concrete, leaving four little tire-dents. Remove it, and when the concrete hardens, you'll have built-in resting places to hold the tires.

Give the concrete a few days to harden before you remove the form and backfill the dirt around the pad.

When it came time to hook up the electrical service to the box at the pier, I hired an electrician. I am totally ignorant of the wiles of electricity, and although hiring him cost more than doing it myself, the peace of mind was well worth it.

The last step is to place the equatorial head on the pier and align it. With the pier and mini-observatory complete, observing is a cinch. When you are finished, simply unplug the clock drive, carry the tube inside, roll the housing back over the mount, secure it, and latch the hasps.

Although the project was a big one for me, I had fun doing it. More importantly, I find I use my telescope far more than I used to and I'm getting much more enjoyment from it. And that's what really counts!

Nicholas Henderson, a banker by profession, was keenly interested in astronomy when he was young. He drifted away from it during his college years, but a year or so ago the bug bit him again.

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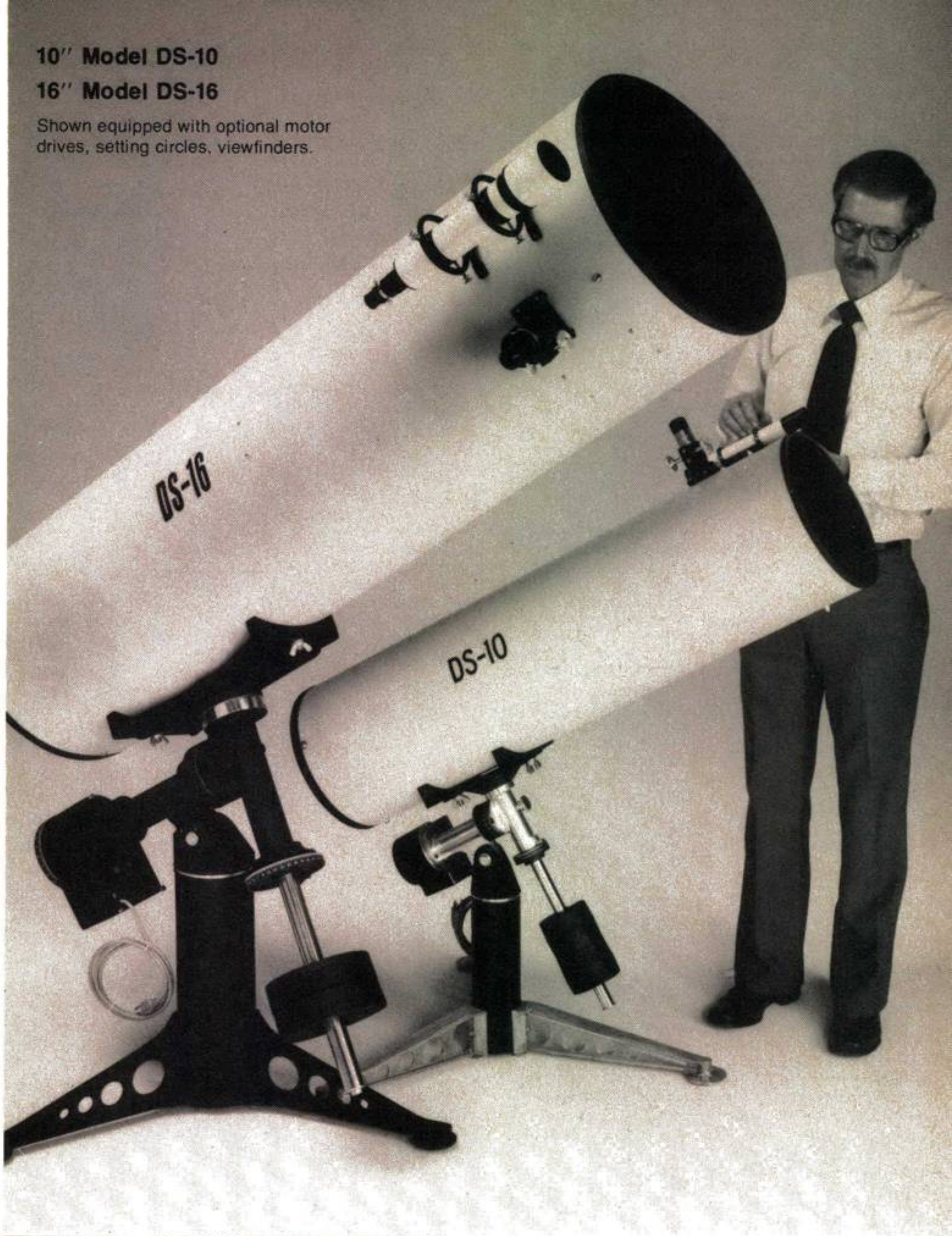

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16″ Model DS-16
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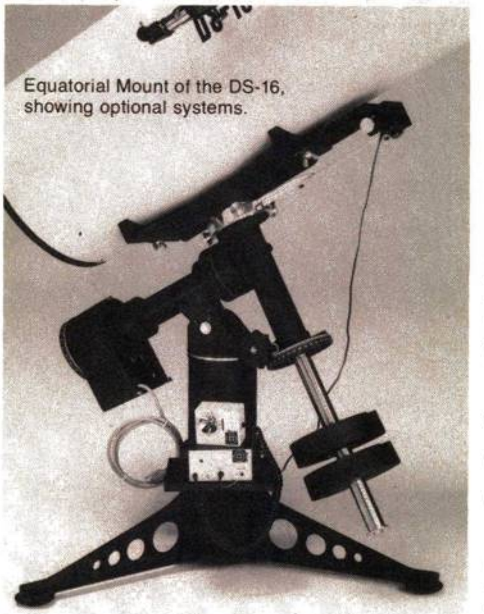

Equatorial Mount of the DS-16, showing optional systems.

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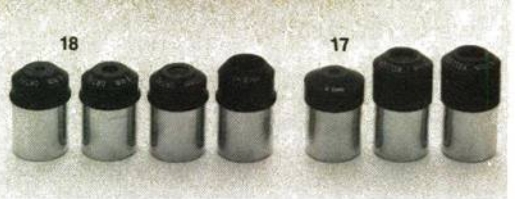

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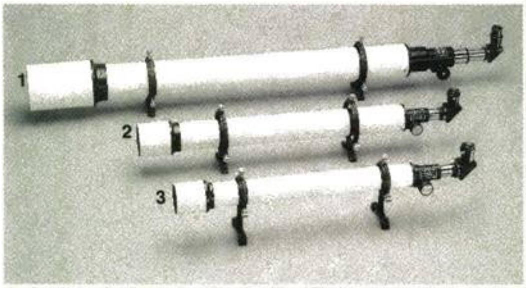

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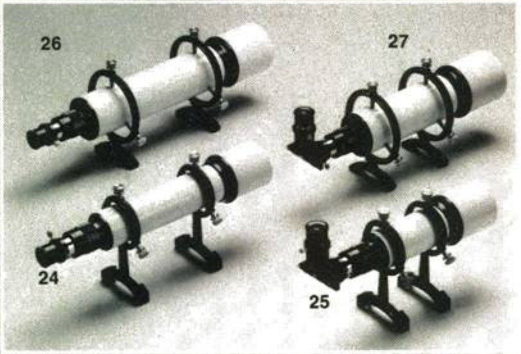

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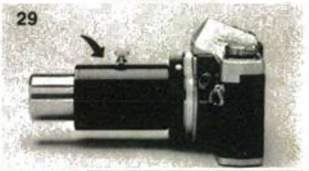
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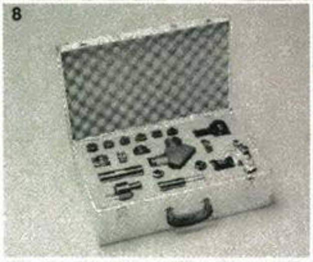
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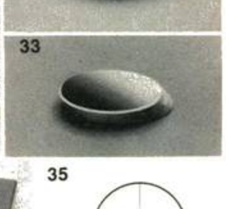
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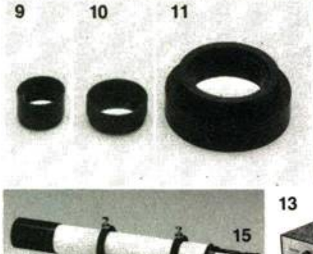

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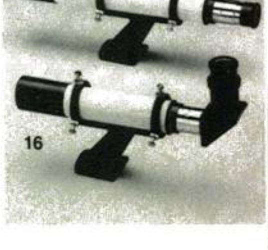

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10″ Schmidt-Cassegrain

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Model 2120
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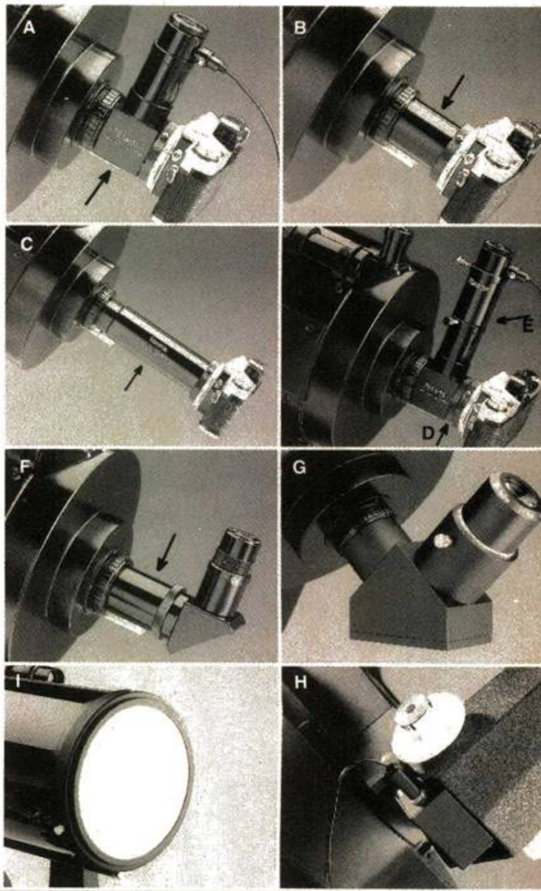
For Nebular Filters, Thread-In Filters, Drive Correctors, Barlow Lenses, Illuminated Reticle Eyepieces, and Erecting Prisms, see the accessories listing on the facing page. These accessories are fully compatible with Meade and Celestron Schmidt-Cassegrains.



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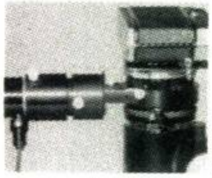

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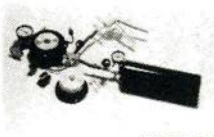

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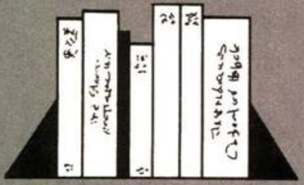

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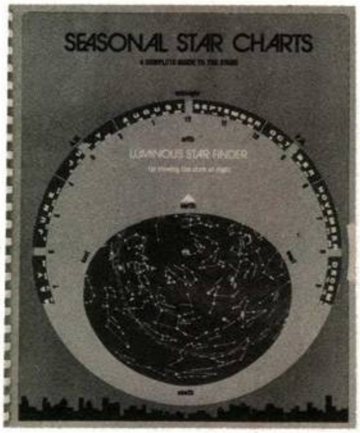

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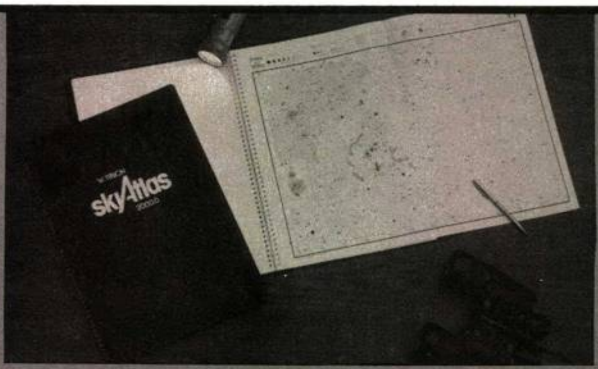

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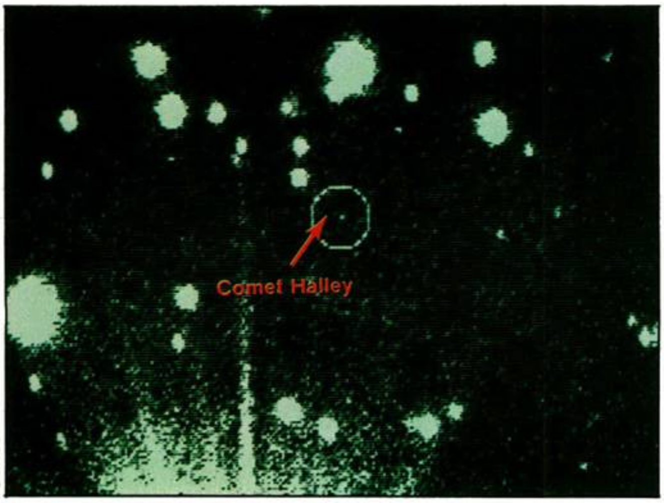

Caltech

Comet Halley Recovered

On October 19, astronomers at Caltech confirmed that a dim point of light they had observed with the 200-inch Hale telescope on Mt. Palomar was Comet Halley on its inbound path toward the Sun.

For the past five years, astronomers at several observatories have been trying unsuccessfully to recover the comet. The Caltech researchers, using a charge-coupled device (CCD) "camera" attached to the 200-inch telescope, finally succeeded — though the comet, at +24.2 magnitude, was nearly at the lower limit of detection for the instrument. The recovery photos were interspersed between regular observations of galaxies and QSOs; since Comet Halley and the most distant quasar are both extremely faint objects, the CCD camera (developed for use on the Space Telescope, and undergoing tests with the 200-inch) was the best instrument to use.

Astronomers David Jewitt and G. Edward Danielson took five 480-second exposures on October 16 at the comet's predicted position. It appeared as a tiny dot moving in the right direction; the comet appeared to have no coma. If it reflects 50% of the light falling on it, then it probably has a diameter of about 2.8 kilometers.

At the time the recovery photos were taken, the comet was moving southwest in Canis Minor. By the middle of this month, it will lie near the coordinates 6h 42m, +9° 20′ in Monoceros, moving slowly toward the northwest — though it is still far too faint to be picked up in amateur-sized instruments. At recovery, the comet was 10.9 AU from Earth and 11.0 AU from the Sun — outside the orbit of Saturn.

On the Way to Jupiter

Since mid-1979, Project Galileo has been a mission in search of a way to Jupiter. The mission's two spacecraft, an orbiter and an atmospheric probe, were originally to leave Earth in early 1982, but delays with the shuttle and its upper stages have repeatedly slipped the launch. In addition, the most recent plan nearly doubled the flight time to the giant planet, cut half the studies of the jovian moons, and raised mission costs by $150 million.

Now, courtesy of the U,S. Congress, Galileo will be delayed another year — but the program's managers aren't complaining. Galileo will arrive at Jupiter a year sooner and be able to do more science when it gets there. At last Galileo has what it needed all along.

When the mission eventually reaches Jupiter, the two craft will conduct the most thorough investigation of Jupiter yet. The probe will carry instruments deep into the planet's atmosphere, and the orbiter will study the magnetosphere, moons, and clouds for twenty months as it circles the planet. In many ways, Galileo is the most complex planetary mission ever attempted.

But this sophistication comes at a price. Together, the orbiter and probe weigh some 2½ tons. Before the shuttle era, they would have left for Jupiter atop a powerful Titan III/Centaur launch vehicle — the same booster that sent the Vikings to Mars and the Voyagers to Jupiter and beyond. NASA has now retired the Titan, so Galileo must ride into Earth orbit aboard the Space Shuttle. From near-Earth orbit, an upper stage carried inside the Shuttle will propel Galileo outward. The problem is that while NASA has several upper stages available, none has enough power to send a payload of Galileo's mass to the giant planet.

NASA originally had a way around the problem: to stack the stages of an Air Force booster, the Inertial Upper Stage (IUS), together. Combined with an especially favorable alignment of the Earth and Jupiter for a launch in January 1982 and a gravity-assist from Mars, the planetary IUS could have sent Galileo to its goal.

By the summer of 1979, however, delays in the Shuttle program meant that the space agency had to postpone the launch to 1984. Less favorable positions of the two planets then meant that the planetary IUS didn't have the kick to send both orbiter and probe off together. The plan changed: they would fly separately, and NASA would pick up the tab for a second craft to carry the probe. A year later the agency decided to drop the planetary IUS because its cost was increasing while its potential power was decreasing.

Another solution was to recapture the capability of the old Titan III/Centaur by modifying its Centaur upper stage to be a shuttle upper stage. Centaur was the perfect upper stage for Galileo because both parts of the mission could fly together again. In addition, the communications industry and the Air Force could also use the Centaur, which could carry almost twice as much weight as an IUS into geostationary orbit around the Earth. The switch in upper stages would open up a new market for the shuttle's launch services.

Despite this, the plan to modify the Centaur raised a storm in Washington. All of the upper stages currently in the Air Force and NASA roster are modestly capable solid-fuel boosters, so a more powerful stage will eventually be built. The only questions remaining were: When would the government pay for the new booster? And who would receive the money to build it?

Many Centaur critics were from aerospace companies who wanted contracts to build a new High Energy Upper Stage; they argued that NASA should wait and develop a totally new liquid-fuel upper stage a few years from now, rather than developing Centaur. Despite their opposition, the Carter administration and Congress approved the Centaur as part of the 1982 budget, but the Reagan administration stopped work on the upper stage a few months later. The new occupants of the White House wanted to cut the federal budget, and eliminating a program only intended for exploring the solar system

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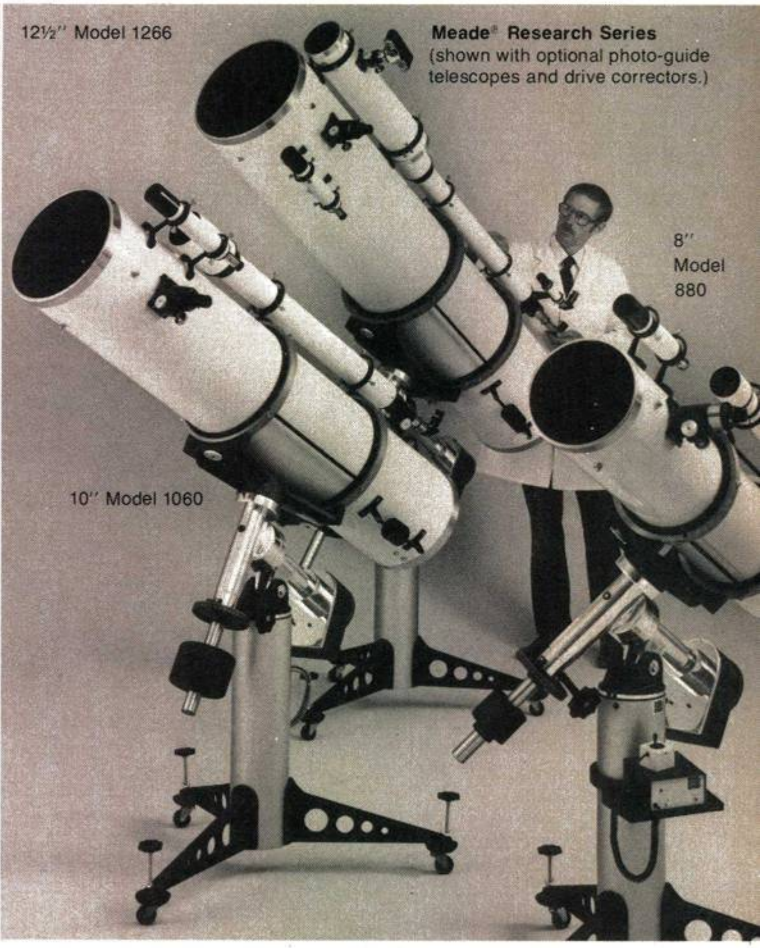
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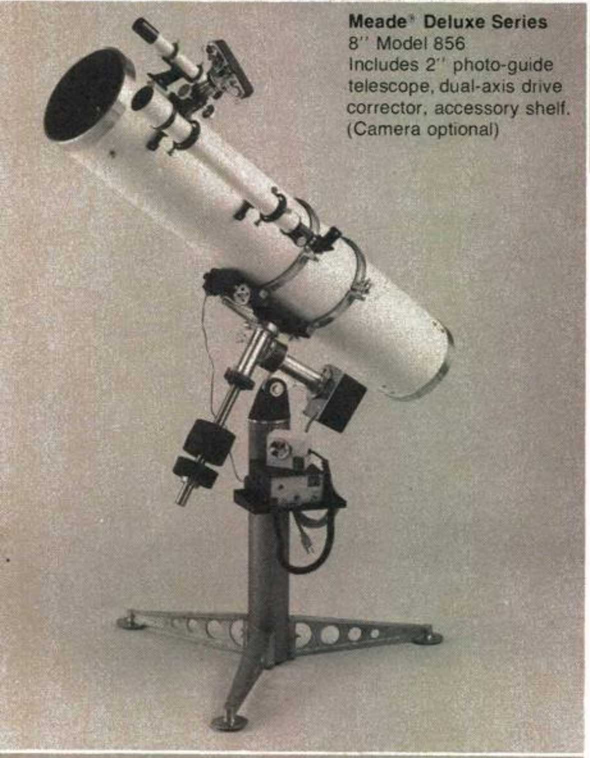
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seemed like a good way.

For Galileo, the change meant a 1985 launch on a two-stage IUS booster that wouldn't have the power to propel the spacecraft and probe directly to Jupiter. For the mission to succeed, the craft would go into a two-year orbit about the Sun. After two years, it would pass the Earth and employ a "gravity slingshot" for its destination. The loop around the Sun added two years to the flight, increasing costs by $50 million for spacecraft development and $100 million for operations. The orbiter would arrive with barely enough fuel for seven to ten encounters with the large jovian moons instead of the original eleven or more encounters — and on top of that, canceling Centaur didn't even save much money, when the higher price for Galileo was added.

NASA was willing to accept the new plan — in fact, its managers were glad to still have Galileo at all since the administration had twice tried to cancel the entire mission. Several congressmen, on the other hand, disliked the idea of paying the same cost for the project while getting less mission. Last summer, they included Centaur funding in the supplemental bill signed by the President. The same act required NASA to stop work on the Galileo version of the IUS.

The Galileo mission to Jupiter will now leave Earth in May 1986, a year later than before, but because the trajectory heads straight for the giant planet, the orbiter and probe will arrive in September 1988, nearly a year earlier than they would have in the IUS mission. In addition, the shorter trip will reduce mission operation costs by $100 million, partially offsetting the extra $50 million penalty caused by the launch delay. The orbiter should have ample fuel when it reaches the jovian system for at least eleven satellite flybys and possibly several more.

Centaur also benefits another scheduled user, the International Solar Polar Mission. This European craft — budget cuts killed NASA's ISPM craft — will use Jupiter's gravity to fly over the Sun's polar region to study the solar magnetosphere high above the plane of the planets. With the new upper stage, ISPM will fly more directly over the Sun's poles and will spend more time over them: 200 days instead of 140. The result will be a more complete understanding of how the magnetosphere of the high latitudes differs from that of the equatorial regions.

Beyond Galileo and ISPM, Centaur is a better way to just about anywhere in the solar system. For flights to the inner planets, Centaur allows heavier but less costly designs. For flights to the asteroids, comets, and outer planets, it opens up new opportunities: NASA has been looking into a series of low-cost flyby missions to drop Galileo-like probes in the atmospheres of the worlds beyond Jupiter. *Van R. Kane.*

Spectacular Display of Rare Type of Solar Flare

Scientists at Sacramento Peak Observatory in Sunspot, New Mexico, have recently detected an extremely rare type of solar flare — a white-light flare — that climaxed a spectacular display of activity on the Sun. Only about 50 white-light flares have been observed in the last century, although thousands of ordinary solar flares may occur during each 11-year solar cycle.

Scientists at the observatory were astonished when the Sun produced five white-light solar flares in a 22-day period last June. The three most powerful originated between June 4 and 6 within a single active sunspot having a diameter of about 51,000 miles — roughly six times the diameter of Earth.

Unlike ordinary solar flares, which can be seen only through special filters, white-light flares — as their name suggests — produce light at visible wavelengths. Donald Neidig, a scientist at Sacramento Peak who is studying the flares, said white-light emission lasts only a few minutes, compared to the average lifetime of about an hour for ordinary flares.

The energy released by such a solar flare, Neidig said, can exceed two billion billion kilowatt hours — enough energy to power a city the size of Washington, DC, for about 280 million years. "Nevertheless," said Neidig, "this is still only a small fraction of the Sun's total radiant output; hence there is no detectable warming of the Earth as a direct consequence of a flare. Flares do, however, produce a wide variety of transient effects in the Earth's magnetosphere and upper atmosphere which result in communication outages, fluctuations in electric power transmission, geomagnetic disturbances, and increases in auroral activity."

White-light flares are important to astronomers because of their ability to produce large amounts of energy on the solar surface. They also provide data which could lead to an understanding of the processes by which this energy is released and transported within the solar atmosphere.

"A fundamental question remains whether flares energize the lower atmosphere of the Sun through bombardment by high-energy electrons and protons or by heat conduction from the flare site in the corona, the outermost part of the Sun's atmosphere," Neidig said. "Protons with velocities approaching the speed of light are known to be accelerated in flares, although their role in producing the white-light emission is not understood.

Neidig added, "Another possibility is that some process in the flares themselves may contribute to the heating of the lower atmosphere. It is precisely these types of questions that studies of white-light flares may answer."

MV Lyrae: Into the Gap

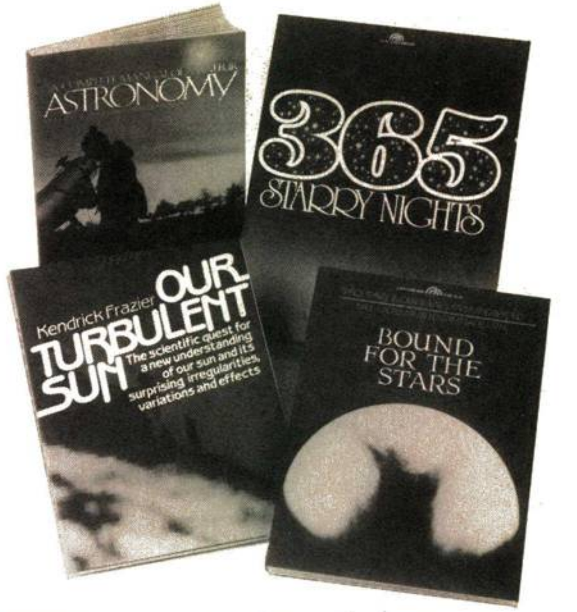
The variable star MV Lyrae, an object known to undergo nova-like outbursts, was a rapidly flickering object of magnitude +12.5 in 1969. The star began to fade in 1979. By July 1980 it had faded to +17.7 and the flickering activity had completely ceased. In September 1980, the star began flickering again, at a slow rate. The object is really a pair of stars orbiting so close to one another that they exchange matter — a close binary. Rapid flickering in such close binary systems is usually caused by mass exchange, so the cessation of flickering strongly suggests that mass transfer had stopped.

Spectroscopic observations confirmed the diagnosis that, after 11 years, the flow of matter between the two stars had ceased. The emission lines seen were no longer those characteristic of mass transfer, but seemed to arise in a corona surrounding the star that had been donating mass. The component stars of close binary systems are not expected to evolve in the fashion typical of solitary suns (see "Contact Binaries: Stars that Touch," ASTRONOMY, December 1982). But what could cause such a sudden change?

As it happens, MV Lyrae lies on the upper edge of the mysterious close-binary "period gap." Many interacting binaries have orbital periods greater than three hours, and many mass-transfer systems orbit one another in less than two hours — but there are no known systems with orbital periods between two and three hours. The strange behavior of MV Lyrae may explain why.

Close, interacting binaries are expected to evolve toward progressively shorter orbital periods, so they must eventually cross into the period gap. These systems transfer material when one of the two stars swells as it evolves, becoming so large that material can easily flow from its surface and fall onto its white-dwarf partner. Weird photometric behavior — such as nova-like eruptions and rapid flickering — results when infalling material strikes an accretion disk around the white dwarf.

A team led by Edward Robinson of the University of Texas suggests that something peculiar must happen to the mass-donating star once the system enters the gap. As the orbital period shortens and a close-binary system teeters on the brink of the period gap, internal changes in the mass donor could cause it to shrink and mass transfer would stop. If this occurred, the system not only would stop flickering but would undergo no sudden eruptions. Such objects would appear to be non-variable and extremely faint — most simply would not be found. "The binary nature of MV Lyrae," argue Robinson's group, "would have remained unknown and unsuspected if it were a non-variable binary at magnitude +17.7." When the period further decreases to two hours, the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ASTRO NEWS

donor star swells once more and mass transfer resumes.

Six other systems that lie on the borders of the period gap exhibit similar "on/off" cycles. But what internal problems could cause the late-type components of close binaries to shrink?

Stars of differing mass have different methods of transferring the heat produced by their nuclear reactions. Those stars with masses greater than 0.3 suns transfer their internal heat through radiation, while those weighing in at less than 0.3 solar masses transfer heat by convection (physical movement of material). Now consider a binary system composed of a 0.3-solar-mass evolved star and a one-solar-mass white dwarf. If the late-type star is in advanced stages of nuclear burning, it is just large enough to sustain mass transfer when the system's orbital period is about three hours.

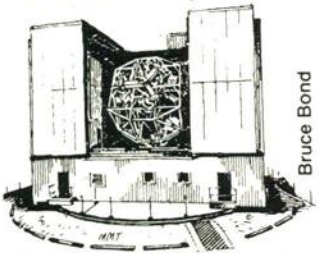
According to Robinson, radiative stars and convective stars respond differently to mass loss. A radiative star contracts during mass loss, while a star with a convective core expands. Since the structure of the late-type star can affect the rate of mass transfer, Robinson's group suggests the following scenario:

A late-type star with a radiative core loses mass to its companion until the binary's orbital period is around three hours. The star has been contracting as it lost mass, and now it is small enough to cut off mass exchange. Inside, the core of the now-shrunken sun begins a switchover from radiative energy transport to convective transport. The core becomes convective, the star swells, mass transfer resumes — and, by the time all this takes place, the orbital period has shortened to lie on the lower edge of the gap at around two hours.

There is evidence against this model. For example, calculations suggest that the atmosphere of the star is more important than its core in determing its response to mass transfer. "Our suggestion," said the researchers, "must be considered as a plausibility argument." Observations require late-type stars in the period gap to behave in a unique way and Robinson's group has identified a structural property that makes the stars unique — the internal change that takes place in their cores when they fall into the gap. Accurate theoretical models will be necessary to decide if this particular property of close binary stars gives rise to the strange period gap.

Light Bucket Searches for Gamma Rays

The world's largest optical "light bucket" is being used to search for gamma ray sources in our Galaxy and beyond. Gamma rays cannot reach the surface of Earth because our atmosphere stops them, but astronomers can still detect them. How? When a gamma ray strikes atoms in the upper atmosphere, it generates a cascade of hundreds of secondary particles, each of which creates a flash of visible light as it slams into more atoms in the atmosphere.



Bruce Bond

These flashes of light are far too faint, and far too brief, to be visible to the eye; this is where the optical "light bucket" comes in. Using the Whipple Observatory Large Aperture Camera, or WOLAC, atop Mount Hopkins in southern Arizona, Whipple Observatory scientists detect the bursts with sensitive photomultiplier tubes placed at its focus. The diameter of the WOLAC facility is ten meters — giving four times the light-collecting power of the Mount Palomar 200-inch telescope.

In the sky, the gamma ray flashes of light appear spread over a diameter of about 2°, so the collector does not need to form a sharp image as large optical telescopes must. However, the direction of the center of the burst can be found with high accuracy. Data is read from the detectors 10,000 times per second and stored on magnetic tape. Later, the tape is played back into a computer for analysis of the data, and the direction of origin of each gamma ray determined.

Gamma ray astronomy provides a unique way of probing the hottest, most energetic regions of the universe. Gamma rays have such high energy that nothing short of violent and catastrophic events such as supernovae can produce them. Already the Crab Nebula, a well-known supernova remnant, has been established as a gamma ray source. Another source, Cygnus X-3, is apparently the strongest in our Galaxy. Astronomer Trevor Weekes, originator of the WOLAC instrument, and his colleagues David Fegan and Neil Porter of University College in Dublin are now working to obtain a better understanding of the physical nature of these objects.

Faster Film Coming

Eastman Kodak Company has announced a new, very fast color negative film. The material, to be called Kodacolor VR-1000, will have an ASA (ISO) speed rating of 1000. Kodak emulsion scientists termed the film the biggest advance in silver halide emulsion technology in 50 years.

"By altering the shape and sensitization of silver halide crystals, we are able to substantially improve their photographic utility," said Dr. L. J. Thomas. "The grain structure . . . affords greater sensitivity than conventional structures, with far fewer compromises in quality than one normally expects with this large an advance in film speed." He hinted that more fast films might be in the offing.

The grains of silver halide have been modified to have a flat, tablet-like shape. Under a microscope, silver halide grains normally appear as cubes, octahedra, or irregular shapes. The new so-called T-grains intercept more light without increasing the amount of silver used in a grain. New films made with it are therefore more sensitive but not more grainy.

"Research had already taken conventional silver halide technology . . . near its practical limit in terms of speed," Thomas said. "We have a way we can greatly extend those limits. This opens up a wide number of fascinating possibilities." Film speeds, which traditionally have doubled every ten years, have been doubling every five years as the result of intense research efforts.

The film, which should have a significant impact on amateur astrophotography, will become available some time in 1983, and is designed for development in Process C-41 chemistry.

ASTRO CALENDAR

January 9-12, 1983	**The 161st Meeting of the American Astronomical Society** (professional meeting). Joint meeting of the Solar, High Energy Astrophysics, and Historical Astronomy Divisions. Contact: AAS, 1816 Jefferson Pl., N.W., Washington, D.C. 20036.
April 22-25	**National Congress of Astronomers,** Astronomical Society of Southern Africa. Contact: M. Andrew Gray, P.O. Box 118, Johannesburg 2000, Republic of South Africa. Phone 011-394941 (Office) or 011-469391 (home).
June 8-12	**Texas Star Party,** Fort Davis, Texas. Contact: T.S.P. '83, Dept. A, 2709 Colonial Dr., Carrollton, TX 75007. Phone (214) 242-4908.
June 13-19	**Joint Meeting of the Astronomical Society of the Pacific and the Western Amateur Astronomers,** on the Kona coast of the Big Island of Hawaii. Contact: Hawaii Meeting, A.S.P., 1290 - 24th Avenue, San Francisco, CA 94122.

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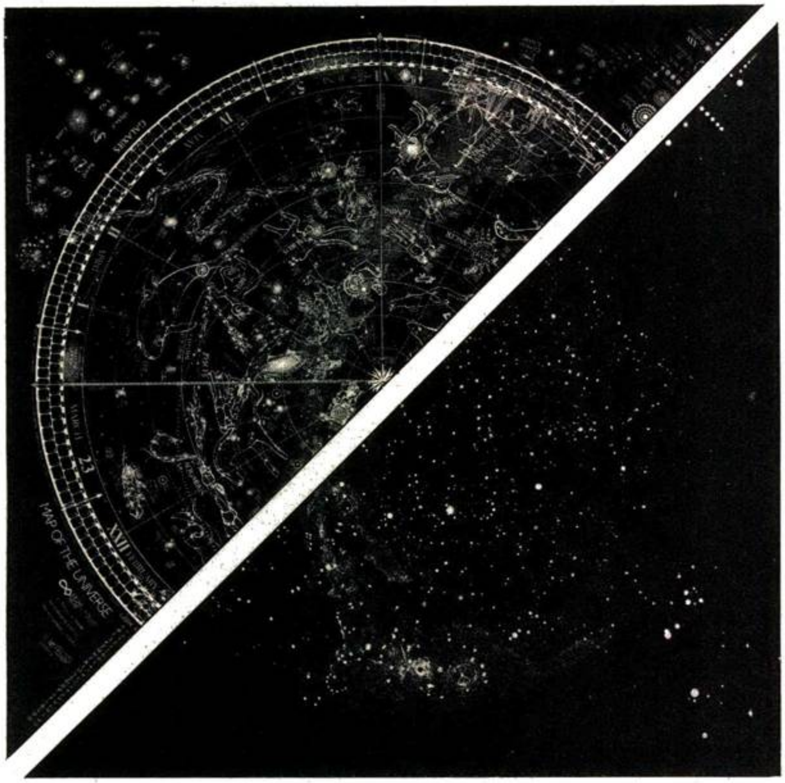

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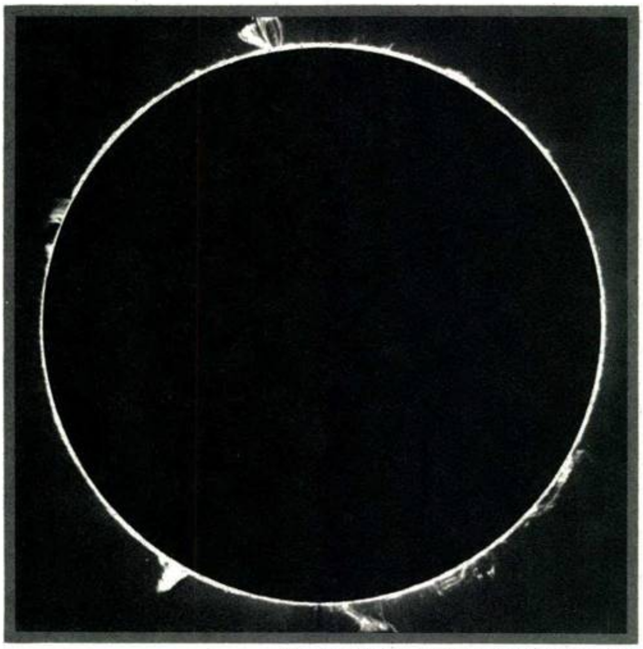
From afar, the Sun's surface appears as a gently glowing yellowish disk. It seems relatively calm. As we lie basking in its rays, we can sense something of its enormous energy output. The Sun appears to be stable and unchanging, a steadily-shining beacon in our daytime sky.

However, when seen through a telescope, this calm picture begins to change: sunspots, plages, and granulation betray violent and awesome events. And if the telescope is equipped with a narrow-band filter that allows only hydrogen light to pass through, the Sun presents an image very different from our everyday experience. We see its surface tattered by swirling storms and titanic "flames" that tower 300,000 kilometers above the solar surface. These "flames" are prominences.

But what are prominences? How are they formed and — more importantly — what role do they play in violent solar processes such as flares? Although they have known about prominences since the early 19th century, astronomers have not yet been able to fully answer these questions. The phenomenon still lies at the frontiers of solar and stellar research.

Prominences had been observed and recorded at solar eclipses for many years, but it wasn't until 1868, when Pierre Janssen turned the slit of his spectroscope toward the Sun, that prominences were detected outside an eclipse. Prominences mainly shine in the light of one element — hydrogen. This property allowed Janssen's spectroscope to separate their light from the brilliant solar glare. Furthermore, spectroscopes revealed Doppler shifts that allowed several Italian astronomers, headed by Father Angelo Secchi, to trace the motions of the prominences and discover the chromosphere — the dim solar "atmosphere" that extends outward about 30,000 km between the photosphere and the corona. In 1877 Secchi coined the term "burning prairie" to describe the appearance of numerous jets of gas at the chromosphere's edge. We now know the jets — which shoot upward to heights of 10,000 km and last between 2 and 10 minutes — as *spicules*.



Mount Wilson and Palomar Observatories

A huge fiery prominence towers over the face of the Sun. Prominences such as this one are giant luminous gas clouds that can reach heights of three million kilometers. Mount Wilson and Palomar Observatories photograph.

In the years that followed, spectroscopy led to further insights, showing that prominences are actually cool extensions of the chromosphere. Researchers found that the chromosphere and prominences are similar in spectral characteristics, indicating similar physical properties.

With the advent of widespread astronomical photography, George Ellery Hale and his colleagues made astounding advances; their spectroheliograms established that limb prominences and dark ribbons of gas on the solar disk, which astronomers had thought were two distinct phenomena, were *really one*. Hale's team showed that the dark filaments are simply prominences seen projected against the bright photosphere.

"Active" and "quiescent" prominences both occur within active regions — areas of sunspot formation, plages, flares, and other phenomena. Quiescent prominences are precisely the dark filaments of gas we find snaking across many an active region. They are, for solar astronomers, a very useful guide to differences in the Sun's magnetic fields. Seen on the solar limb, they appear as "curtains," "tree trunks," "hedgerows," and "loops" — each a class of quiescent prominences based on general form.

The quiescent prominences are relatively long-lived — sometimes lasting for 6 to 8 solar rotations of about 25 days each. They may survive after all of the sunspots in the parent active region have dissipated, which is normally only 1 or 2 solar rotations. Their very longevity could be responsible for the erroneous impression that quiescent prominences exist independently of active regions.

In contrast, active prominences are relatively transient. Their eruptions tend to coincide with solar flares — themselves very transient phenomena. Two examples of this type of prominence are "surges" and "sprays" — the spray being a more violent version of a surge. Hα photographs of surges and sprays show material being driven upward from the chromosphere, and their Doppler shifts confirm this. The velocity of ejection can, in fact, reach hundreds of kilometers per second, and the matter can attain an altitude of 100,000 km before falling back — or it can even escape entirely, as is often the case with sprays. The jet-like spicules, which literally make up the chromosphere, are "mini-prominences."

Spicules, surges, and sprays are often described as *eruptive prominences*, which gives the impression that quiescent prominences cannot erupt. However, this is certainly not the case: the largest eruptive prominence on record, designated "Grandpa" and observed in 1946, was initially quiescent, and had been visible for months before its pyrotechnic eruption.

Observationally, then, there are many types of prominences. But what makes them tick? This is much easier to ask than to answer, and the problems in classifying prominences should alert you to their physical complexity — a complexity which still taxes astrophysicists in their attempts to model them.

To begin, we know that prominences are composed of a material we call plasma. A *plasma* is made up of charged particles; it is a gas which is highly ionized, a gas whose constituent atoms have each given up at least one electron. In the case of the Sun, which is predominantly hydrogen, the plasma is primarily composed of a soup of electrons and protons. The presence of so many unattached charges makes the plasma a good conductor of electricity.

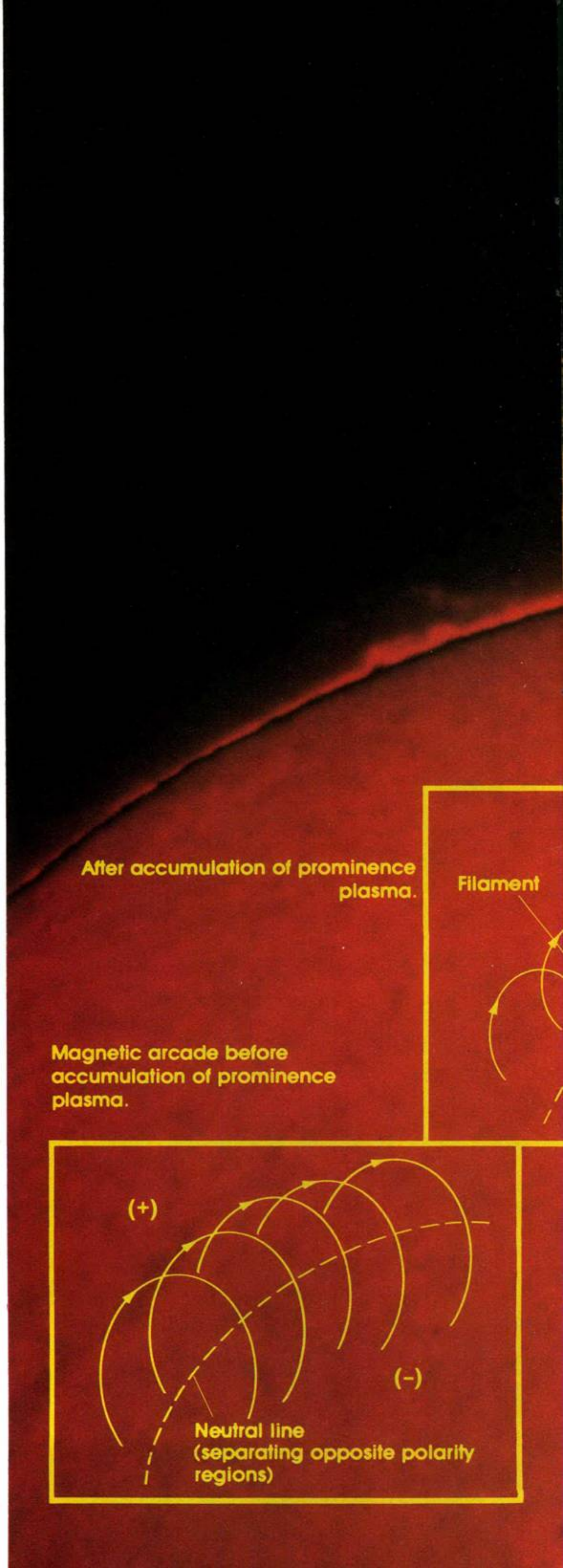
Now consider the environment. The Sun is an extremely active generator of magnetic fields. As particles move in a magnetic field, they create an electric field which, in turn, creates another magnetic field opposing the original field. This means it takes energy to push a proton or electron across magnetic field lines. We must expect complex interactions when such a highly conducting gas lies in the vicinity of powerful, localized magnetic fields like those on the Sun (see "Sunspots," ASTRONOMY, May

PROMINENCES

BY PHILIP A. STAHL

Immediately after totality two magnificent prominences appeared. One of them (more than three arc-minutes in height) blazed with a splendor that is difficult to imagine. The analysis of the light showed me that it was formed by an enormous column of incandescent gas, principally composed of hydrogen.

— Pierre Janssen,
after observing the total eclipse of 1868


After accumulation of prominence plasma.
Filament
Magnetic arcade before accumulation of prominence plasma.
(+)
(-)
Neutral line (separating opposite polarity regions)

Vladimir Vudler took this picture of solar activity using a 14-inch f/11 Schmidt-Cassegrain, Fujichrome RD 100 emulsion, and an Hα filter. He photographed the surface for 1/125 second, the prominences for 1/4 second, and combined the two.

1980).

One exotic interaction is the "freezing" of a magnetic field into a plasma. When this happens, the magnetic lines of flux are forced to move *with* the plasma and are dragged along with it wherever it goes.

When does field freezing occur? Whenever the magnetic fields get so scrambled up the plasma can drag them along with it. But how do they get scrambled? Solar physicists judge "scrambling," or turbulence, by a dimensionless quantity called the Reynolds number, which relates the size, speed, and viscosity of a moving fluid system. The importance of the Reynolds number is that when it is large, turbulence in the fluid stream is inevitable.

Solar physicists use a variation of the Reynolds number that takes magnetic effects into account. This "magnetic Reynolds number" for the plasma in prominences is typically 10 million, or even more — indicating a large amount of turbulence. The electrically charged plasma makes an excellent electrical conductor when it flows in a turbulent stream, so solar physicists assume the plasma has zero electrical resistance when the magnetic Reynolds number is very high.

This is, however, a tricky assumption. If the plasma crosses any magnetic field lines, a voltage will be induced within it and with zero resistance, an infinite current will ensue — a physical impossibility. The way out of this dilemma is to assume that the plasma does not have to cross magnetic field lines. If the field lines are not cut, then they must move with the plasma, and are thus "frozen in" to it. This means that great turbulence, infinite conductivity, and a "frozen in" magnetic field are consistent with one another.

At the same time, "induction drag" always occurs when field lines are frozen into plasma. Induction drag forces the plasma to move *along* the field lines.

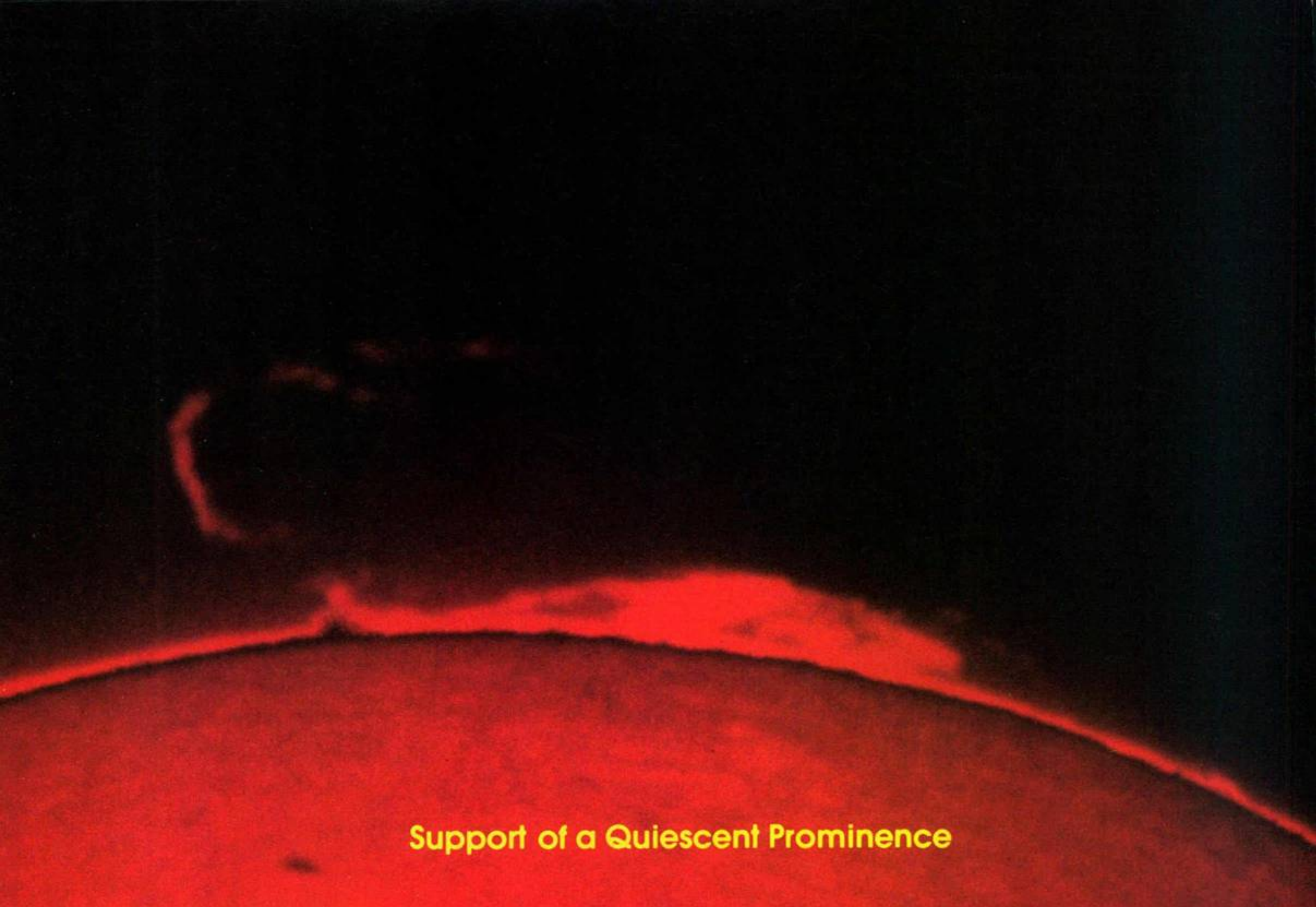
How does this help us understand the behavior of prominences? Remember that prominence plasma is up to 90% ionized and very turbulent, so we expect it will be in the frozen-in condition.

Think of a powerful flare erupting, accompanied by jets of plasma being shot outward. What becomes of this material? If it is ejected at a sufficiently high velocity, it will escape completely into space. The charged particles from such a flare spray may reach our planet in three days, producing noticeable effects such as the aurorae.

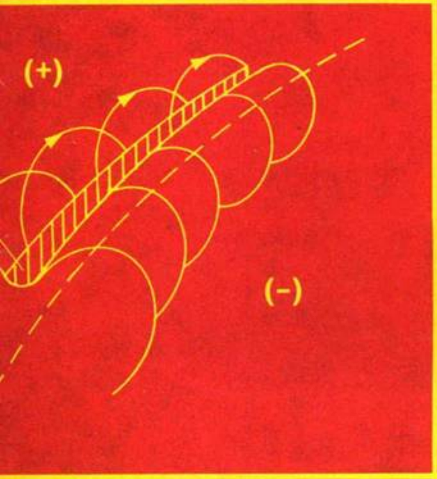
For a less energetic ejection, or surge, the charged particles will reach a high altitude, perhaps 100,000 kilometers, and then rain back down under the pull of solar gravity. On the way down, this condensing plasma may encounter one or more magnetic loops, or other magnetic field structures scattered through the lower corona. What happens then?

Induction drag will constrain the plasma to move along pre-existing field lines. As a result, the magnetic fields will become visible, their forms outlined by the infalling plasma. The differences in types of prominences are shown by the diversity of the magnetic fields they reveal.

In the case of the long-lasting quiescent prominences, there must be some way in which they can be supported against the Sun's gravity for prolonged periods. Magnetic field lines provide this support. Picture a series of closely-spaced loops joining areas of opposite polarity, a structure solar physicists call a magnetic arcade. As the cool, dense plasma accumulates over the arcade, the magnetic field lines increase their support of the overlying weight, but also sag at the same time. A magnetic "canyon" forms which can, to some extent, insulate the prominence plasma from the hotter plasma of the surrounding corona. As long as

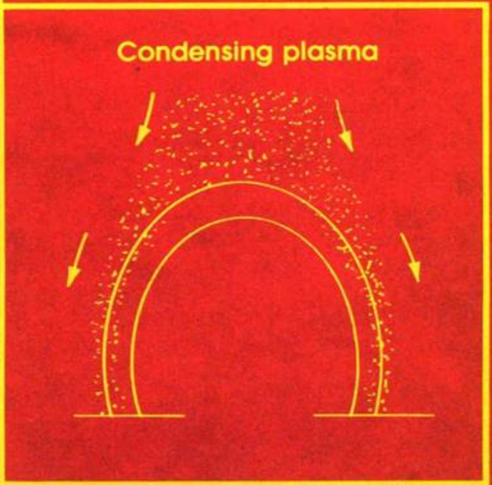


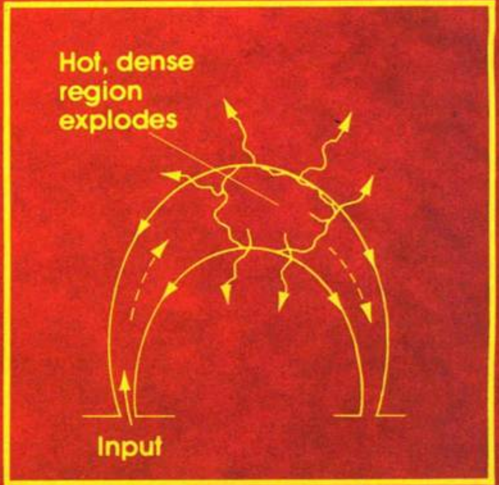
Support of a Quiescent Prominence



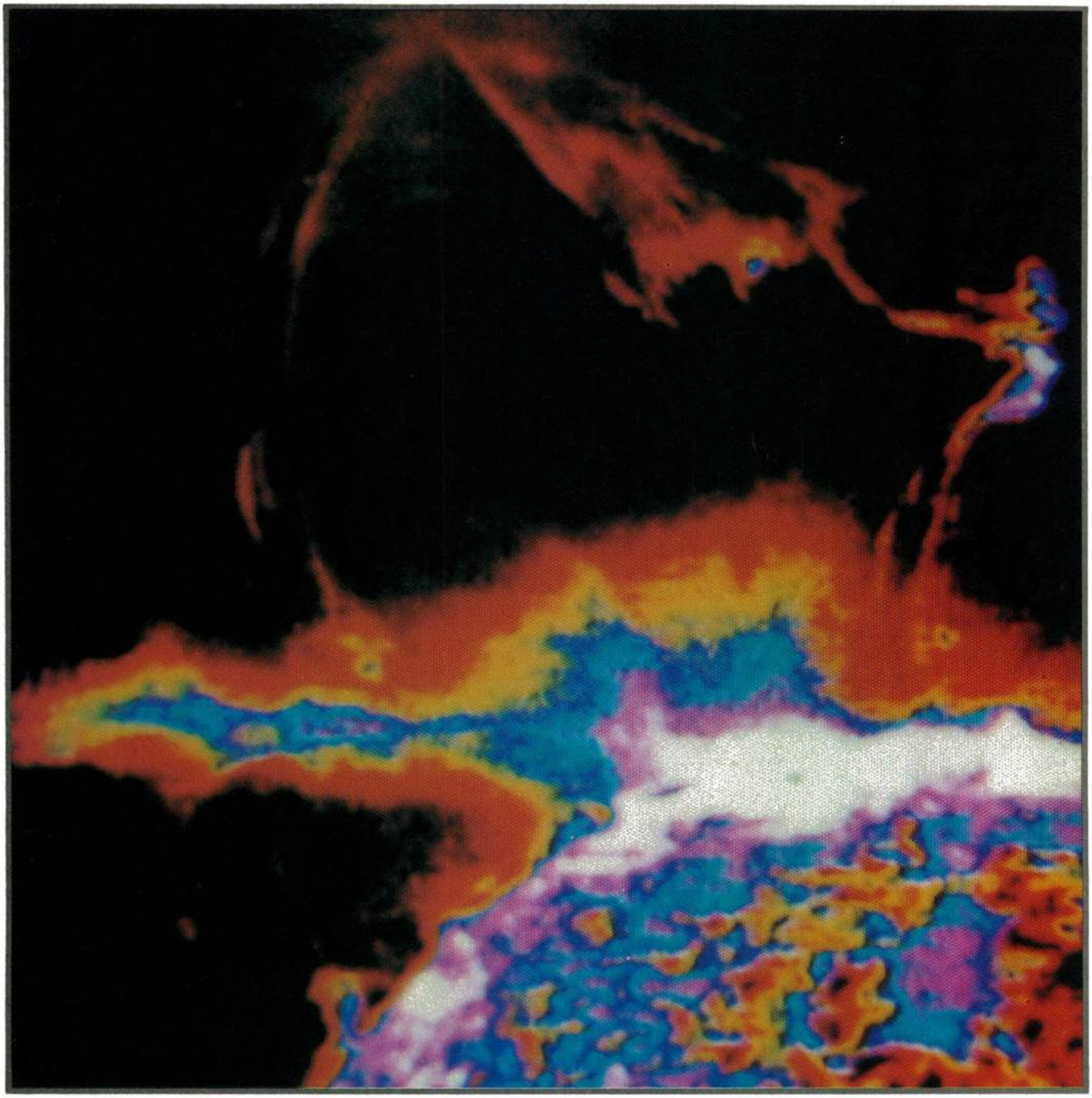
In injections, charged particles enter the loop from below, moving around it (dotted arrows) and becoming hot from collisions with surrounding gas. A hot, dense region eventually forms at the apex of the loop and explodes with plasma, moving down both legs.

In condensations, plasma moves under free fall in the solar gravitational field. In this case it is constrained to follow the field, outlining its form.


Condensing plasma


Hot, dense region explodes
Input

Condensations/Injections



This Skylab photograph shows an enormous jet of helium gas flowing outward from the solar surface. The false-color imagery indicates temperature: the white and lavender areas are the hottest. Naval Research Laboratory photograph.

magnetic fields support the prominence, and its plasma stays relatively insulated, the prominence survives quiescently.

It is conceivable that too much plasma could pile up in the magnetic canyon so that the supporting field lines eventually snap like rubber bands. This could explain the occurrence of some flares in old active regions, where quiescent filaments and prominences are located. Some so-called "two-ribbon" flares may be produced in this way, when the initially supported plasma falls along with the filament lines and "crashes" to the base of both sides of the magnetic loop. When the infalling matter reaches the lower chromosphere, its gravitational potential energy converts into thermal energy, resulting in a flare.

Filaments are generally of great interest to solar physicists as precursors of flares. The ejection of a filament to a great height and its later disappearance — called *disparition brusque* — often heralds the onset of a flare. Although research has revealed some degree of association between filaments and flares, more work is necessary to establish the causal links. Currently, solar physicists still cannot agree on whether activated filaments *result* from flares or *cause* them.

The prominence phenomenon is certainly not an easy aspect of our Sun to understand — many points of our picture of how they work are still in a process of refinement and revision. Certainly, it would be a rash oversimplification to claim that the diversity of forms apparent in prominences is due to any single process. The term "prominence" may actually describe a number of independent phenomena.

Further progress in understanding prominences will, to a large degree, depend on how well solar physicists apply the principles of magnetohydrodynamics — that esoteric area of physics which deals with the behavior of plasma in strong magnetic fields. The situation is so complex that the

Induction and Field Freezing

The principles of electromagnetic induction — which also apply to prominences — were first advanced by English physicist Michael Faraday. The basic idea is that a voltage difference is induced between two points in a circuit whenever the magnetic flux is changing, or whenever part of the circuit is moved perpendicular to the existing field lines.

What is the simplest type of induction circuit that will demonstrate this? Suppose we move a bar magnet through a coiled conducting wire connected to a current-measuring device such as a galvanometer. Fewer field lines are cut at (1) than at (2). This, in effect, is what induces a voltage and current: the rate of change of magnetic flux.

Two further actions can confirm this. First, the bar magnet may be held stationary in the very center of the coil, in which case no current will register, since there is no change of flux. Second, the bar magnet may be thrust through at a *faster* rate, in which case the deflection of the needle on the measuring instrument is *greater*. The size of the induced voltage and current is proportional to the rate of change of flux.

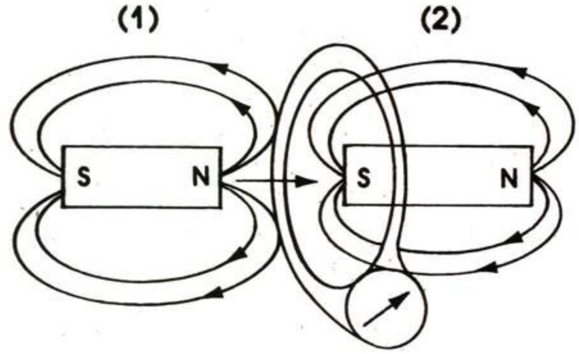
It is important to note that the same effects can be produced by holding the magnet fixed and moving the *coil* relative to it. The relative motion is what matters.

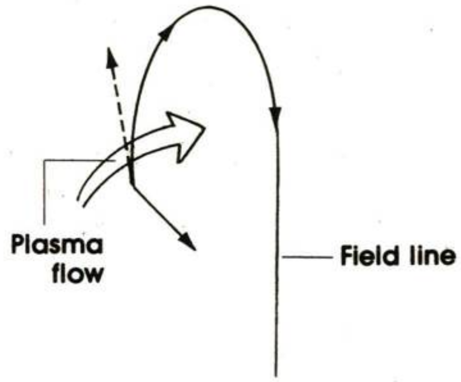
To apply all of this to prominences, consider the hypothetical case of an ejected plasma moving transverse to the magnetic field lines as shown below:

The plasma flow represents the motion relative to the existing field — leading to a change in magnetic flux and an induced voltage. The direction of the induced current may be found by using Fleming's *right-hand rule*: If you extend your forefinger, thumb, and second finger at right angles to each other, then your forefinger illustrates the field direction, your thumb the motion direction, and your second finger shows the direction of the induced current (see diagram).

Since the plasma would have a very high magnetic Reynolds number, which is proportional to the velocity, and the velocity of mass ejection is quite large, the conductivity of the plasma would be infinite. Thus, even a minuscule induced voltage, due to very small relative motion, would produce an infinite current from the plasma physicist's version of Ohm's law: $j = \sigma E$, where E is induced voltage, σ is conductivity, and j is induced current.

The only way to avoid this unrealistic situation is to require the plasma motion to *follow* the field lines rather than cut across them. This is precisely the condition for field freezing.





only way solar physicists *can* quantitatively grapple with the phenomenon is to make extensive use of a hypothesis, or starting approximation, in which plasma properties such as density and temperature may vary in only one dimension rather than three — or it may ignore all motion, or even do both.

Researchers can then examine the problem in static, rather than dynamic terms. They can pay attention only to the magnetic and gravitational forces acting in equilibrium. This has the advantage of turning a complex set of nonlinear differential equations — all but intractable — into a simplified set which can be solved. The solutions provide us with a tentative insight into what happens under certain ideal conditions. But the region of the solar atmosphere where prominences occur is a dynamic environment where physical properties like temperature, density, and magnetic field strength change rapidly — so a gap exists between simplified prominence models and the complex reality.

Further progress also hinges on obtaining better observational resolution in both space and time. We already have ample evidence that prominences possess a fine-scale, ribbon-like structure. This filigree structure weaves delicately in and out of dark filaments like fine strands of a rope. It is, however, nearly at the limit of resolution set by ground-based "seeing" (about 0.5″ to 1″ of arc). Astronomers need to observe what happens at the level of these fine structures to better comprehend prominences as a whole. How, for example, do the small structures respond when hit by a shock wave from a distant flare? Could this be responsible for making filaments disappear? We can't truly answer such questions until we obtain finer image resolution, perhaps using the Space Telescope.

Resolution in time is no less important than angular resolution in answering many current questions. At present, we don't know whether flares activate prominences, or the converse. Movie cameras are invaluable tools in this respect, but many observing stations outside the U.S. don't have them. The question of prominence formation — whether from infalling condensations, mass injections, or both — could perhaps be settled through better spectral resolution and motion-picture cameras.

The study of prominences, an aspect of the larger study of our own nearby and familiar star, takes us to the frontiers of stellar research. At frontiers, we invariably find more questions than answers, and enough problems to occupy researchers for some time. The consolation lies in knowing that despite their maddening complexity, prominences offer an almost unparalleled display of celestial grace and beauty. This is something we all can appreciate — even those who have never heard of magnetohydrodynamics!

Philip Stahl is a physicist at the University of the West Indies in Barbados. His research interests include solar flares, sunspots, X-ray binaries, and variable stars. His last article for ASTRONOMY was "Sunspots," in May 1980.

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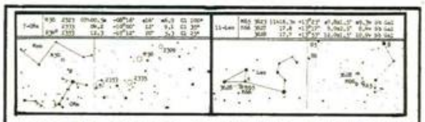

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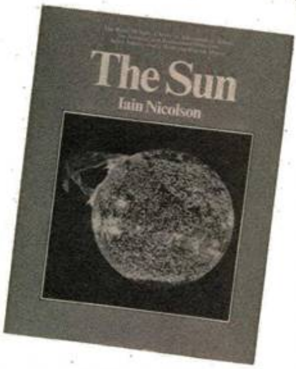

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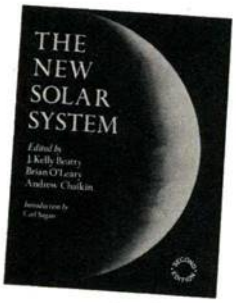

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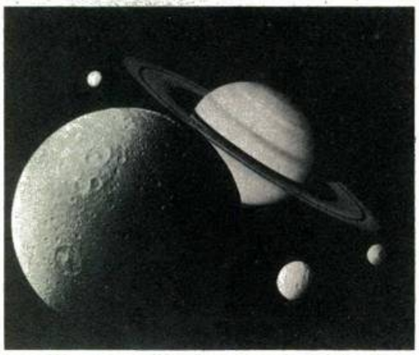

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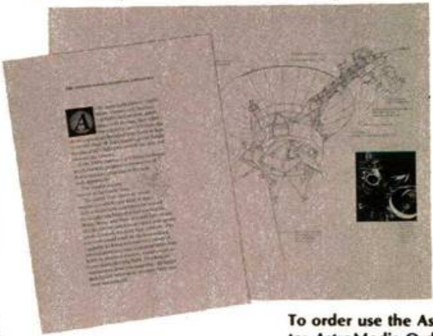

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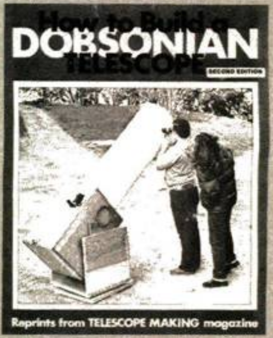

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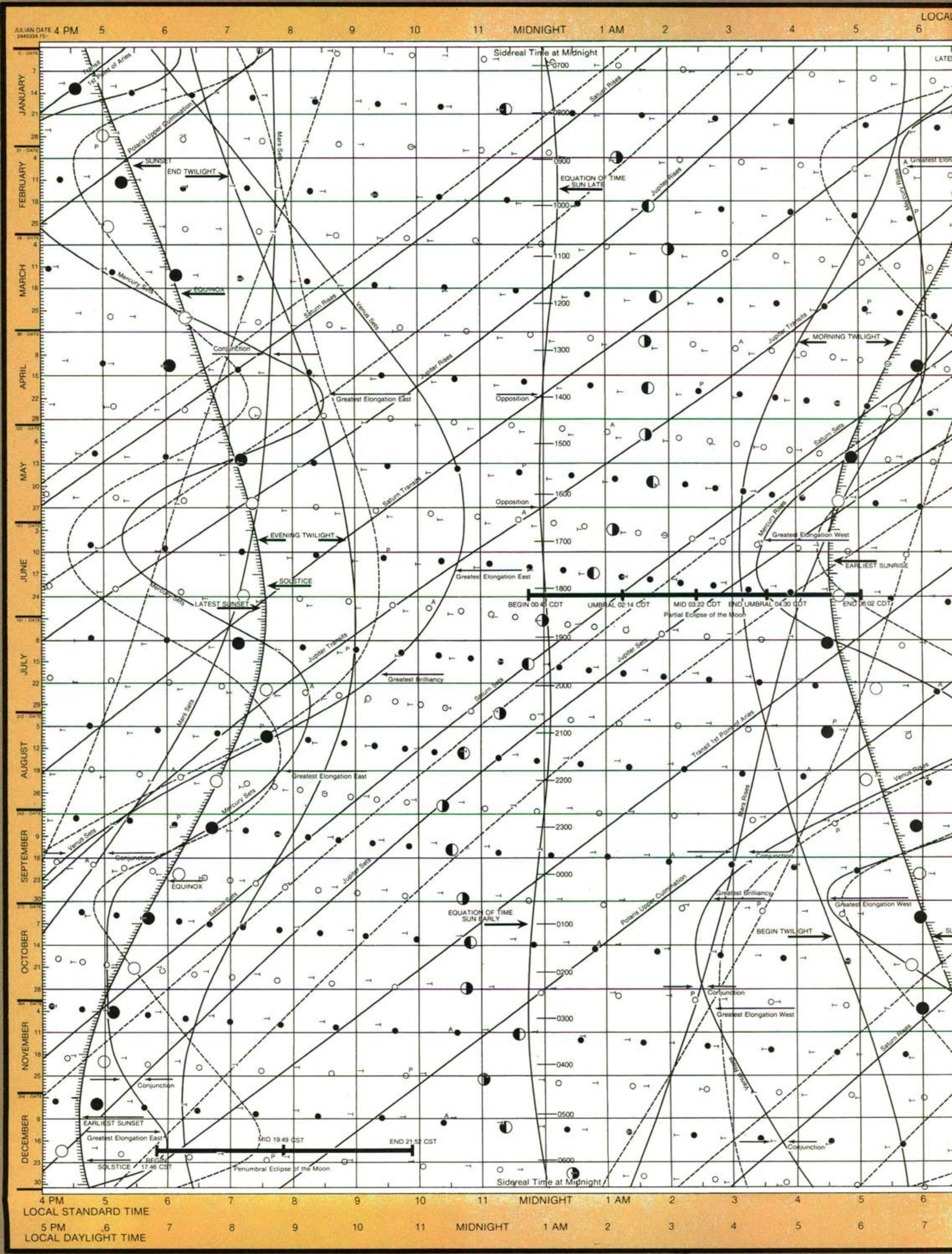
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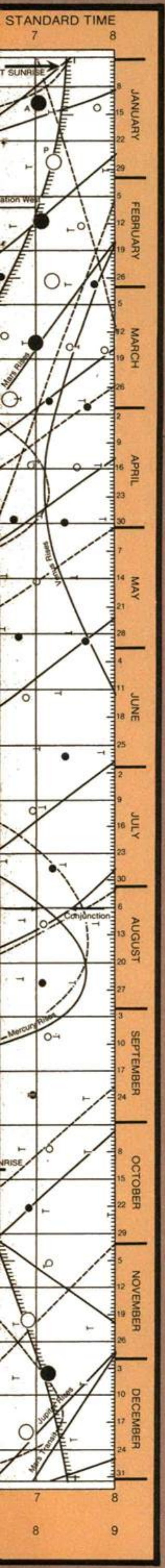
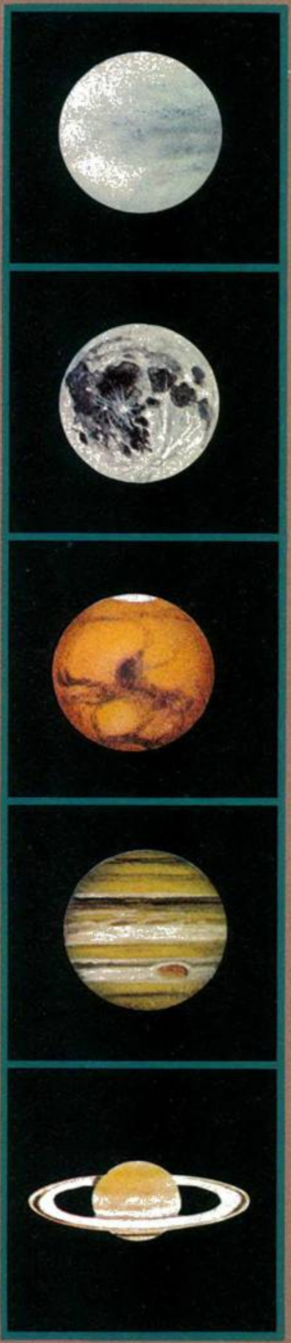
the great 1983 almanac skychart





Squiggle, squiggle, snake, twist, dot, dot, dot. . . . It sure looks impressive — but what *is* it?

It's the Graphic Timetable of the Heavens for 1983, a unique method of condensing a year's celestial events onto a single page.

To help you understand how to use it, here's a description of what it shows: From top to bottom along the edges, it lists every day in the year, month by month. Extending across from left to right are the nighttime hours between 4 p.m. and 8 a.m. local time; midnight runs down the center.

Each line running diagonally down the page represents the time when a given celestial event occurs — Jupiter-rise, for example, or Saturn-set. (Notice how they get earlier as the year progresses?) Running vertically down the page are other lines that curve back and forth, showing the times of sunset, Venus-set, or when twilight begins and ends. Since the time of these events depends on your latitude, the solid lines indicate times for an observer at +40° latitude, while the dotted lines give times for the equator.

Nor is this all: The chart even shows the day-to-day lunar events and phases: The little black dots that march in a row across the chart show the times of moonset, while the hollow dots show moonrise. First Quarter, Full, Last Quarter, and New are displayed as extra-large dots on the days they occur. Both of the 1983 lunar eclipses appear, together with the times of the main events.

● Moonset at 40° Latitude
○ Moonrise at 40° Latitude
– Moonrise/set at Equator
● New Moon
◐ First Quarter
○ Full Moon
◑ Last Quarter

Let's take a sample night, draw an imaginary line from left to right, and follow it to discover what events transpire: On the late afternoon of January 14, the first event shown is the transit of the "first point of Aries," otherwise known as the vernal equinox, at 4:25 p.m. The next event is sunset at a minute before 5:00. At 5:22, Mercury sets, followed very shortly by moonset. The next event (at 6:19) is Venus-set, followed by equatorial Mercury-set a minute later.

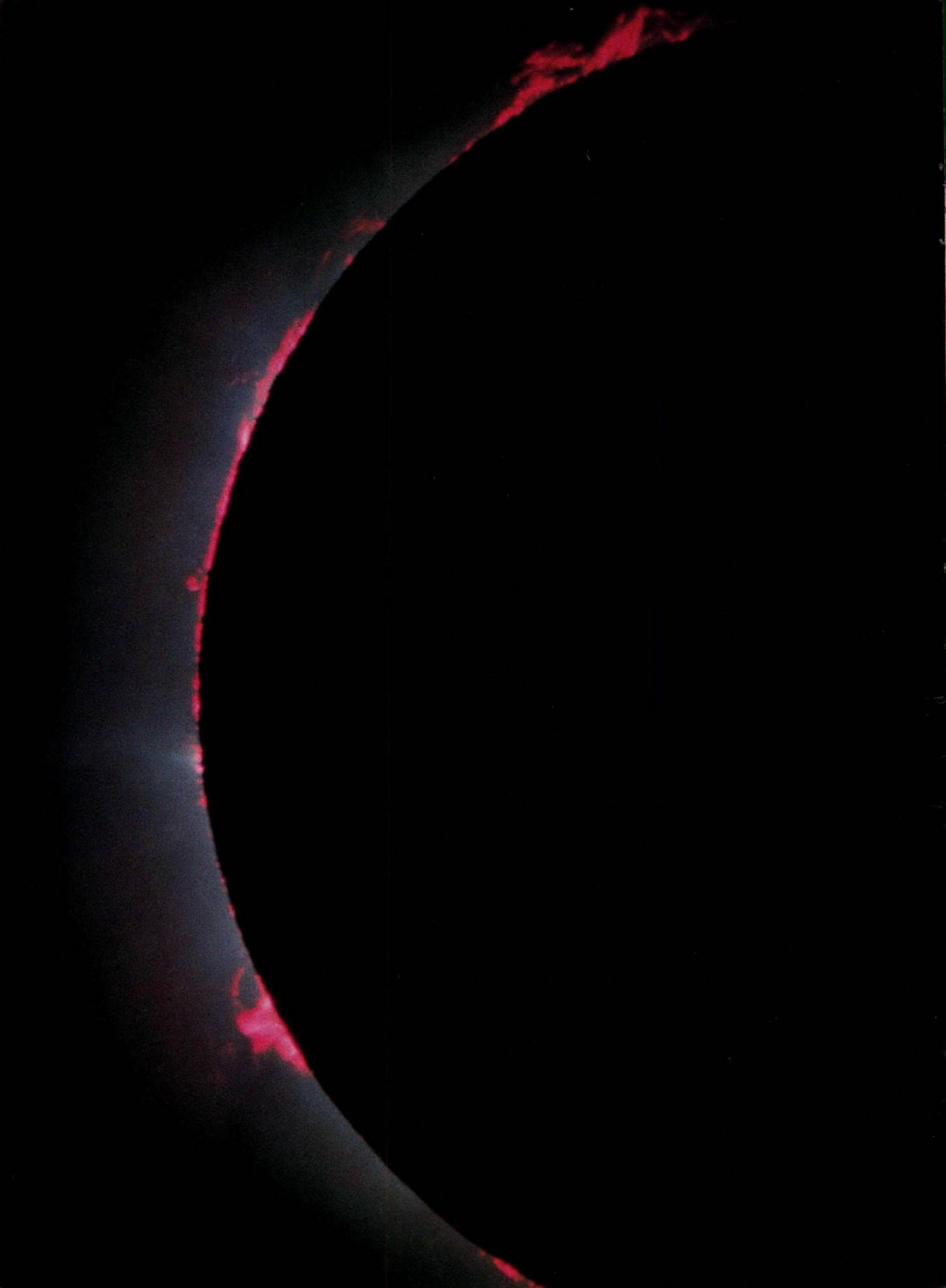
At 6:35 comes the end of astronomical twilight, and the upper culmination of Polaris (when it lies directly above the pole) is at 6:46. Equatorial Venus-set comes at 7:27, Mars-set at 7:44, and equatorial Mars-set at 8:30.

Then there are no special events until shortly after midnight, when the dotted line shows equatorial Saturn-rise at 12:33 a.m., followed by Saturn-rise at 1:03. (The vertical squiggle just to the right of the midnight line shows that on this date, the apparent motion of the real Sun is 8 minutes behind, or late, compared to the mean Sun — an important correction for anyone who has a sundial.)

Equatorial Jupiter-rise and Jupiter-rise happen at 2:31 and 3:38, respectively. Morning twilight begins at 5:44, equatorial Mercury-rise is at 6:14, Saturn transits at 6:33, and Mercury rises at 7:10 — just 9 minutes before the Sun comes up at 7:19 on January 15.

That's all there is to it. You scan across from left to right at each night's location and tick off the events as they occur. Then, to get the local times, simply look up or down at the head or tail of the chart and read them off. At first, a chart like this seems totally bewildering — there's so much detail. But look it over carefully, and trace out the events of several nights — soon you'll get accustomed to its handy, compact way of presenting a lot of basic observing information.

Editor's note: a larger (16" by 20"), 6-color version is also available from AstroMedia Corp. for $6.95 (postpaid) or from Scientia, Inc., 1815 Landrake Rd., Baltimore, MD.



the backyard astronomer

orion

Mercury

You'll have two opportunities to view Mercury this month: The first comes early in January, when the planet finishes its appearance in the evening sky. The second comes late in the month, when Mercury emerges from inferior conjunction into the morning sky for the start of its best apparition all year.

The evening apparition will be short; by about the 10th, the planet will be very close to the horizon in the southwest. But before it disappears into the glow of twilight, it will have a conjunction with Venus on the evening of January 6. (The conjunction actually takes place around 10h UT on the 7th, when the pair is out of view from North America.) At that time, Mercury will lie 2° north of Venus. Mercury's disk will be a little over 8" of arc across, Venus' about 10". Though lower in the sky than Mercury, Venus will be considerably brighter: -3.4 magnitude to Mercury's +0.4.

After passing through inferior conjunction on January 16, Mercury will move swiftly into the morning sky. You can probably catch sight of it by the morning of the 20th, very low in the east-southeast. Between then and the end of January, it will rise to an elevation of about 7°, 45 minutes before sunrise. During this period, its phase will change from a crescent 6% lit and 10" of arc across to a wider crescent, 38% lit and 8" of arc across.

See the box on page 84 for a list of this year's elongations of Mercury and Venus.

Venus

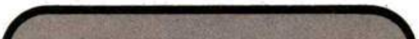
As the year opens, Venus is a bright object low in the southwestern sky after sunset. During January it will climb higher each night, passing Mercury on its way, until by the end of the month it will be almost 10° high, 45 minutes after sunset.

Telescopically, Venus is still small and nearly round — not yet much of a sight for the observer.

The February 26, 1979 total solar eclipse was the subject of a collaborative effort by Steven Wissler, Charles Mitchell, Allen Schiano, Adam Hall, and Ed Hattendorf. They used a 10-inch f/13.5 Schmidt-Cassegrain scope and a 1/60-second exposure on 64 ASA film to earn the "Best Astro-Photo" award for January.

Earth

Earth makes its closest approach to the Sun (perihelion) at 16h UT on January 2; the Sun will be 146.51 million kilometers away.



Mars

Mars remains in view throughout January, although it is sinking lower each night. It is visible as a bright orange-red object in the west-southwestern sky after sunset. 312 million kilometers away on the 15th, Mars displays a +1.3 magnitude disk 4.5" of arc in diameter.

Asteroids

1 Ceres (magnitude 8.5) lies in central Sagittarius, just north of the handle of the "Teapot." It will remain difficult to see until late in the month. Its positions:

9th: 18h 54m 11s, -25° 31.6'
19th: 19h 11m 58s, -25° 21.8'

Ceres rises around 7 a.m. local time at mid-month.

2 Pallas (10.1) is in central Ophiuchus. Its positions:

9th: 17h 32m 53s, +3° 53.0'
19th: 17h 47m 23s, +4° 22.7'

Pallas rises around 3:30 a.m. local time on the 15th.

3 Juno (10.7) is in conjunction with the Sun on February 3 — it will be too near the Sun to be seen this month.

4 Vesta (8.1) lies in eastern Aquarius. Its positions:

9th: 22h 58m 52s, -12° 48.7'
19th: 23h 14m 53s, -11° 00.9'

Vesta sets about 7 p.m. local time at mid-month.

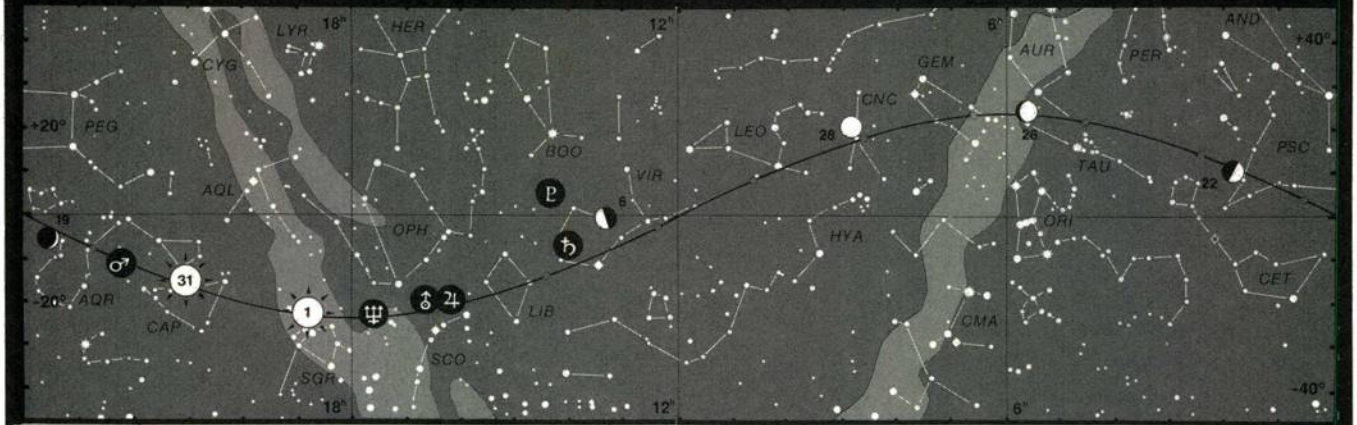
To facilitate plotting their positions on a star atlas, all asteroid coordinates are for the epoch 2000.0.

Jupiter

When you train your scope on Jupiter, now a prominent object in the morning sky, the first thing you see in a low-to-medium power eyepiece is a whitish oval disk flanked by a few points of light. Looking more closely at the disk, you'll see two greyish-brown bands across its middle — the jovian North and South Equatorial Belts. The famous Great Red Spot, which actually looks more grey than red, is a feature of the South Equatorial Belt. You may have to watch for several mornings in a row before you spy it on one of its passages across the disk.

But Jupiter has other markings, too. Between the equatorial belts and the polar regions, each hemisphere of Jupiter's disk is striped by two or three faint lines — the Temperate Belts — separated by brighter Zones. Spotting the Temperate Belts is difficult, especially in small instruments,

planetary data january 1983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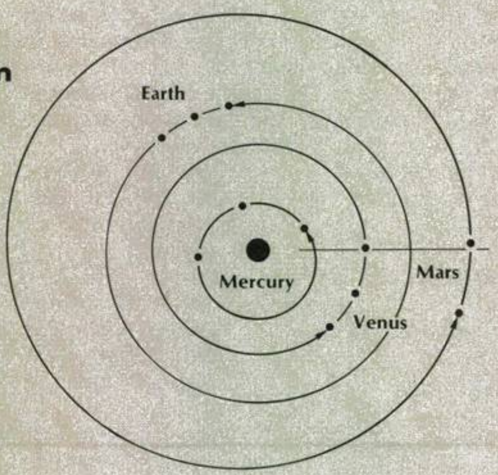
inner solar system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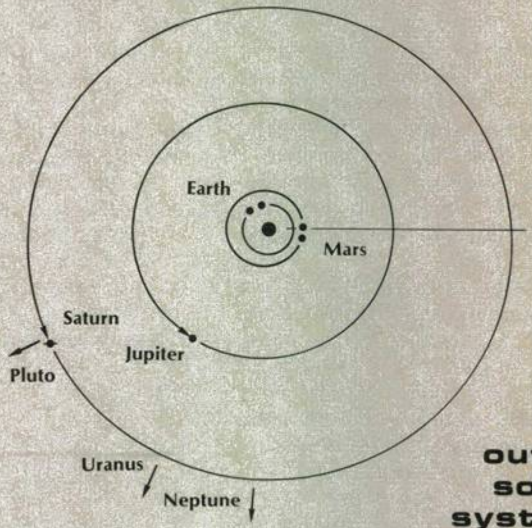

Earth
Mars
Saturn
Jupiter
Pluto
Uranus
Neptune

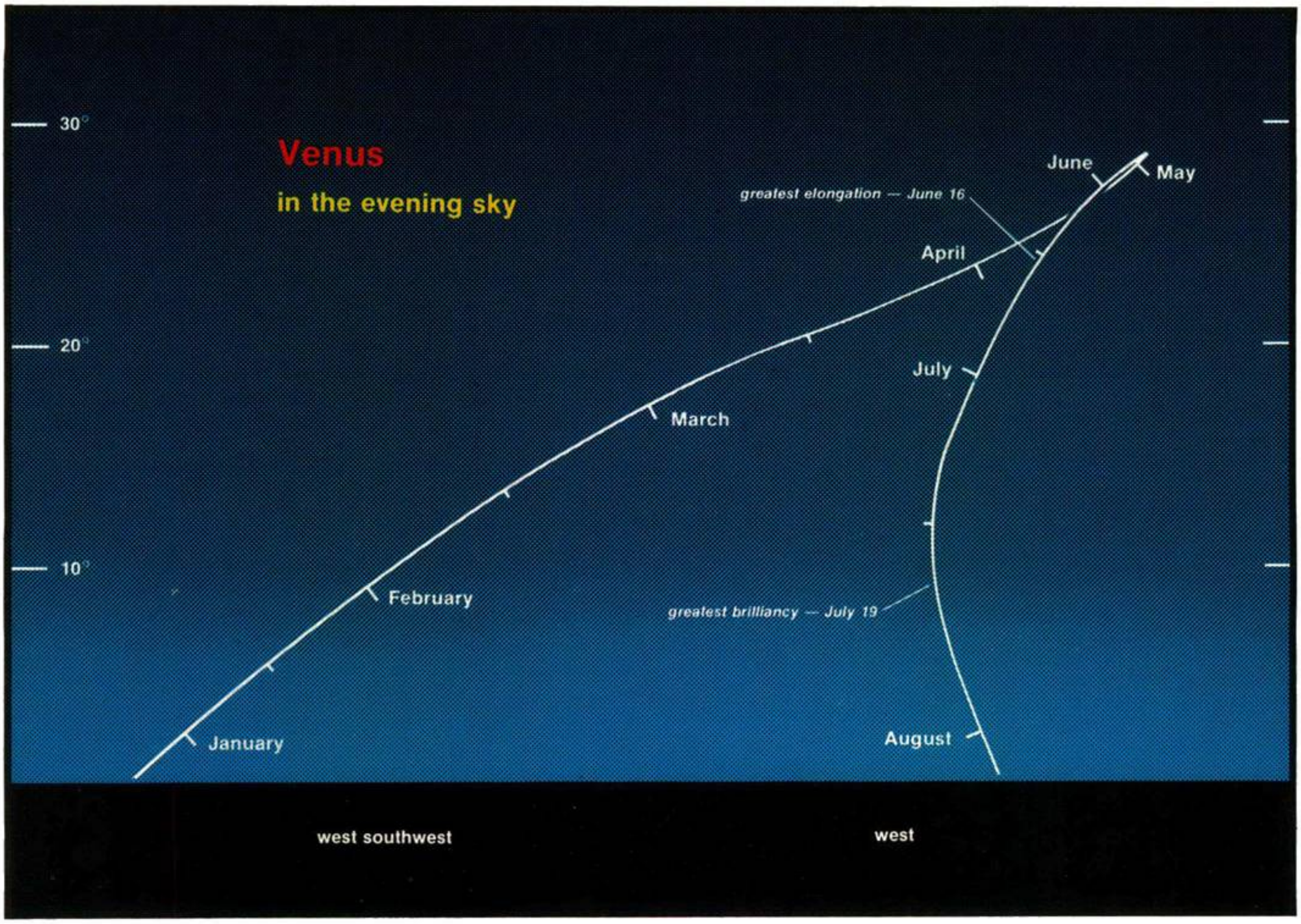
		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (1983.1)	Dec.
Sun		1	−26.8	32.6′	—	0.98	—	—	248°00.0′	18h 43.5m	−23°03.9′
		15	−26.8	32.6′	—	0.98	—	—	294°16.1′	19h 44.6m	−21°15.9′
		31	−26.8	32.5′	—	0.99	—	—	310°32.6′	20h 51.9m	−17°35.9′
Mercury	☿	1	−0.3	7.0″	55%	0.96	0.33	23°26.1′	299°03.0′	20h 07.6m	−21°14.7′
		15	+2.5	9.9″	2%	0.67	0.32	108°36.9′	296°15.0′	19h 53.5m	−17°58.5′
		31	+0.5	8.0″	41%	0.83	0.40	186°52.8′	286°44.4′	19h 13.4m	−20°08.6′
Venus	♀	10	−3.3	10.4″	96%	1.62	0.73	327°28.7′	304°52.8′	20h 32.2m	−20°20.3′
		31	−3.3	10.8″	94%	1.55	0.73	0°48.3′	331°07.8′	22h 16.6m	−12°21.0′
Mars	♂	15	+1.4	4.5″	96%	2.09	1.39	351°14.4′	327°33.0′	22h 02.2m	−13°08.9′
Jupiter	♃	15	−1.4	33.0″	100%	5.96	5.39	235°42.3′	243°19.9′	16h 07.8m	−20°05.8′
Saturn	♄	15	+0.8	16.9″	100%	9.86	9.74	208°01.2′	213°16.3′	14h 09.4m	−10°27.4′
Uranus	⛢	15	+6.0	3.5″	100%	19.58	18.92	246°32.6′	244°46.9′	16h 23.5m	−21°28.7′
Neptune	♆	15	+7.8	2.4″	100%	31.15	30.27	267°27.0′	266°23.5′	17h 50.3m	−22°12.7′
Pluto	♇	15	+13.9	0.1″	100%	29.98	29.91	207°29.2′	206°32.3′	14h 13.3m	+4°37.4′

moon data

Last Quarter	January 6 at 4:00
New Moon	January 14 at 5:08
First Quarter	January 22 at 5:33
Full Moon	January 28 at 22:26
Last Quarter	February 4 at 19:17
New Moon	February 13 at 00:32
Apogee: January 14 at 5h	406,561 km
Perigee: January 28 at 11h	356,984 km

universal time

Astronomers the world over use an unambiguous system of time reckoning — Universal Time (UT) — based on a 24 hour clock. Times in The Backyard Astronomer are UT unless otherwise noted. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska and Hawaii, 10. For example, if an event is to happen at 03:00 hours UT on February 2, then EST for the event is 10 *p.m.*, February 1. Likewise, 03:00 UT on March 5 becomes, in PST, 7 p.m., March 4.



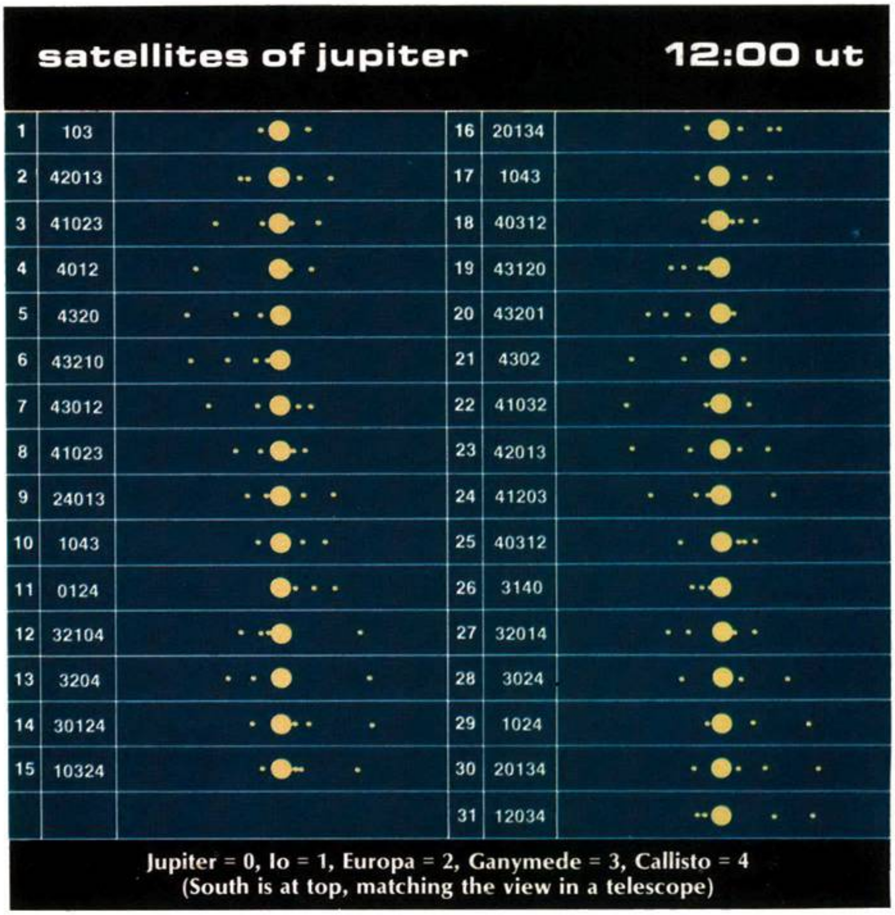
Venus' path in the evening sky during the first eight months of the year shows a swift climb to maximum elevation, then an even swifter drop as it heads for inferior conjunction. The assumed time is 45 minutes after local sunset, and the view is that of an observer at 40° N; the path will vary slightly in other latitudes.

because their contrast relative to the neighboring Zones is very low. This is where steady seeing, moderate aperture, and above all, practice, come to the rescue. Take notes on what you see — and watch how you improve over even a few weeks.

Saturn

Although Jupiter has four bright moons (called the Galilean moons after the discoverer), Saturn has only one — a "Huygenian" moon named Titan. Having a diameter of some 5140 kilometers, Titan is substantially larger than our own Moon, and can be seen as an 8th magnitude dot of light that circles Saturn once every 15 days 23 hours.

Titan is bright enough to be picked up in binoculars, but using a small telescope will make identification a cinch. This month, Titan will be at western elongation from the planet on the 7th and 22nd; eastern elongations come on the 15th and 31st. Between



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6	43210
7	43012
8	41023
9	24013
10	1043
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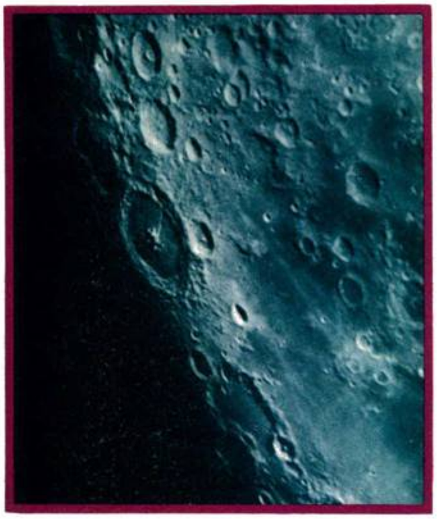
13	3204
14	30124
15	10324
16	20134
17	1043
18	40312
19	43120
20	43201
21	4302
22	41032
23	42013
24	41203
25	40312
26	3140
27	32014
28	3024
29	1024
30	20134
31	12034

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)



Above: The large lunar crater Petavius lies near the evening terminator in Jean Dragesco's photo. Right: Finding the Great Nebula in Orion is easy; finding the elusive Horsehead Nebula is not! Jack Newton photographed it with a 16-inch f/5 Newtonian and a 14-minute exposure on 400 ASA film in a cold camera.

western elongation and eastern elongation, Titan is behind Saturn in its orbit; between eastern and western, it lies in front of the planet.

Uranus

Uranus will pass the invisible division between Scorpius and Ophiuchus around the 10th of January. At that point it will be roughly halfway between two 5th magnitude stars, Psi (ψ) and Rho (ρ) Ophiuchi, that lie a few degrees north of bright Antares. This region rises around 5 a.m. local time on the 15th; you won't have long to observe before morning twilight interferes.

Neptune

Neptune's course during January is eastward; already well into the Milky Way's star-littered outskirts, Neptune will be hard to identify, except under high powers, for the next several years. Look for it now about 1° north of the Trifid Nebula (M-20) and about 10 to 12 minutes of right ascension west. During the last week to 10 days of the month, Neptune will pass through the northern edge of the sparse open cluster, NGC-6469.

Meteors

The only significant annual shower occurring in January is the Quadrantid, which will reach peak activity on the 3rd. From a dark-sky site, the typical zenithal hourly rate is about 40 — though the displays in some years have been substantially heavier. The radiant lies near the common boundaries of Hercules, Draco, and Bootes, in the now-obsolete constellation of Quadrans Muralis — a group devised by J.-J. de Lalande in 1795.

close-up on orion

Astronomers have long known that the region of the constellation Orion is a showplace of stellar activity. It is enshrouded in a huge cloud of molecular hydrogen gas, enveloping hot new stars that have formed out of the great area of nebulosity. In particular, the area around the Great Nebula in Orion (M-42) provides the best view of a stellar birthplace that northern-hemisphere observers have. The Orion Nebula seems to be a "bubble" blown on the cold molecular hydrogen cloud by the stars within it. Many examples of bright and dark nebulosity can be observed throughout the area. Fine open star clusters, formed out of the gas, are also abundant. With so much "current"

activity going on in Orion, it is no wonder that the constellation is one of the favorite locations of all for deep-sky observers.

The Orion Nebula, one of the most intriguing of all sky objects, has been observed since prehistoric times as a fuzzy glow in Orion's sword. Known more intimately since the invention of the telescope, M-42 is a glorious sight in small backyard telescopes. In a 6-inch reflector, you'll be able to perceive the nebula's greenish color and faint curved structure easily, but won't be able to see much detail. In 10-inch and 12-inch telescopes, under good seeing conditions, the Great Nebula is a spectacle: its greenish light is much brighter, its structure is fairly bright and intricate, and curving lanes of nebulosity fan southward on each side of the nebula. In large, short-focus telescopes, M-42 is so detailed that it cannot be sketched accurately. Such a sight is an inspiration that observers don't soon forget.

M-42 is composed of hot particles of hydrogen, helium, and other trace elements, which shine by fluorescence caused by **Theta^1** (θ^1) **Orionis,** a set of four stars known as the "Trapezium." This quadruple star is therefore the source of light that allows us to study

M-78

Lee Coombs

M-42 and its surrounding area. The four stars, designated Theta^1 Orionis A, B, C, and D, shine at magnitudes of 6.8, 7.2, 5.4, and 6.3 respectively; star A is actually an eclipsing binary with a period of 6.5 days and a magnitude range of 6.7 to 7.7. The stars are young and hot, and form the center of a loose cluster of stars formed out of the Orion nebular complex.

The Great Nebula itself occupies some 1°x1.5° of sky, and the total integrated magnitude of M-42 and associated stars is 3.0 — very large and bright in comparison to most deep-sky objects. Not as luminous is **NGC-1981**, an open star cluster that lies a scant 25′ north of the Great Nebula, and contains 45 stars ranging from magnitude 8 to 10 in an 18′ diameter field. It is a fine sight in an 8-inch telescope, and is visible as a hazy circle of stars in a 2-inch refractor. With a total magnitude of 8.0, it is even impressive in very large instruments.

Just north of M-42 lies **M-43**, an 8th magnitude detached portion of nebulosity. The two nebulae are actually part of the same cloud, but appear to be detached because we only see the very dense portions of emission nebulosity. In small telescopes, M-43 resembles a circular glow around the 8th magnitude illuminating star; in telescopes of 10 to 12-inch aperture, it resembles a bloated comma.

Another nebulosity lies on the other side of Orion's belt: **M-78** is a small, bluish reflection nebula. Composed of minute dust grains, it shines — unlike M-42 — by reflected starlight. At magnitude 9, and measuring some 8′x6′, it is one of the best examples of a reflection nebula observable with 6 to 8-inch telescopes; it is much easier to observe than the Merope Nebula in the Pleiades. Two or three conspicuous stars involved with the nebulosity can be seen with an 8-inch scope.

Planetary nebula **NGC-2022** is a challenge for owners of small telescopes, but is a fine example of a rather "stellar" planetary in large instruments of 16 to 20 inches. The nebula measures about 30 arc-seconds across, and dimly glows at magnitude 13 — a difficult target to identify with anything less than a 6-inch scope. Its central illuminating star shines at 14th magnitude — can you observe it?

Even more difficult to observe is the dim band of milky light that protrudes south from Zeta (ζ) Orionis, designated **IC-434**. This faint strip of emission nebulosity, radiating at about 14th magnitude, has caused a lot of frustration to dedicated deep-sky observers. The reason for this is that the **Horsehead Nebula**, B-33 — a small black patch of dark nebulosity that almost defies observation — is silhouetted against this faint strip. The secret to observing the Horsehead is to use a fairly large-aperture, wide-field telescope, preferably at least 12 inches in mirror size, and to make the attempt only under excellent seeing conditions. The tiny patch of dust is indeed observable, but only a relatively select group of observers has ever seen it.

NGC-2022

Martin Germano

Two open star clusters are interesting targets for backyard observers — **NGC-2169** and **NGC-2194**. Both are fairly bright. NGC-2169 contains 20 stars, the brightest of which are 8th magnitude, packed into a diameter of only 4′. The total magnitude of the group is 6.4, and it contains the multiple star Σ 848. By contrast, NGC-2194 covers twice as much area as NGC-2169, but packs in five times as many stars, the brightest shining at magnitude 12. Thus it is, at magnitude 9, much dimmer, but also much "richer." Both clusters have much to offer at the eyepiece.

Pi^3 (π^3) is a 3rd magnitude star in Orion that is very close to us — only 26 light-years away. It is a yellowish-white star whose true luminosity is three times greater than the Sun's. Seen from the viewpoint of this star, our Sun would appear to be a 4th magnitude yellowish star lying in Ophiuchus near globulars M-10 and M-12.

Slightly farther away than Pi^3 is **Betelgeuse**, designated Alpha (α) Orionis. A red supergiant, it is one of the largest known stars; were it placed in our solar system, its awesome diameter would swallow up Mars and perhaps even extend out to Jupiter — it ranges from 500 to nearly 1000 times larger than the Sun. It is also an irregular variable star, pulsating between magnitude 0.4 to 1.3.

Betelgeuse was the first star other than the Sun to have its disk examined by astronomers. Using a technique called speckle interferometry, Kitt Peak observers used the 4-meter telescope to record false color images of "starspots" on Betelgeuse in 1975.

The star lies at a distance of 520 light-years, and is intrinsically very bright. Our Sun, seen from the same distance, would glow dimly at magnitude 10.8. Betelgeuse is supermassive: if it doesn't find some way in which to lose a lot of this mass, it may one day die in a spectacular supernova explosion. From a distance of 520 light-years, that would indeed be quite a show.

elongations of mercury & venus — 1983

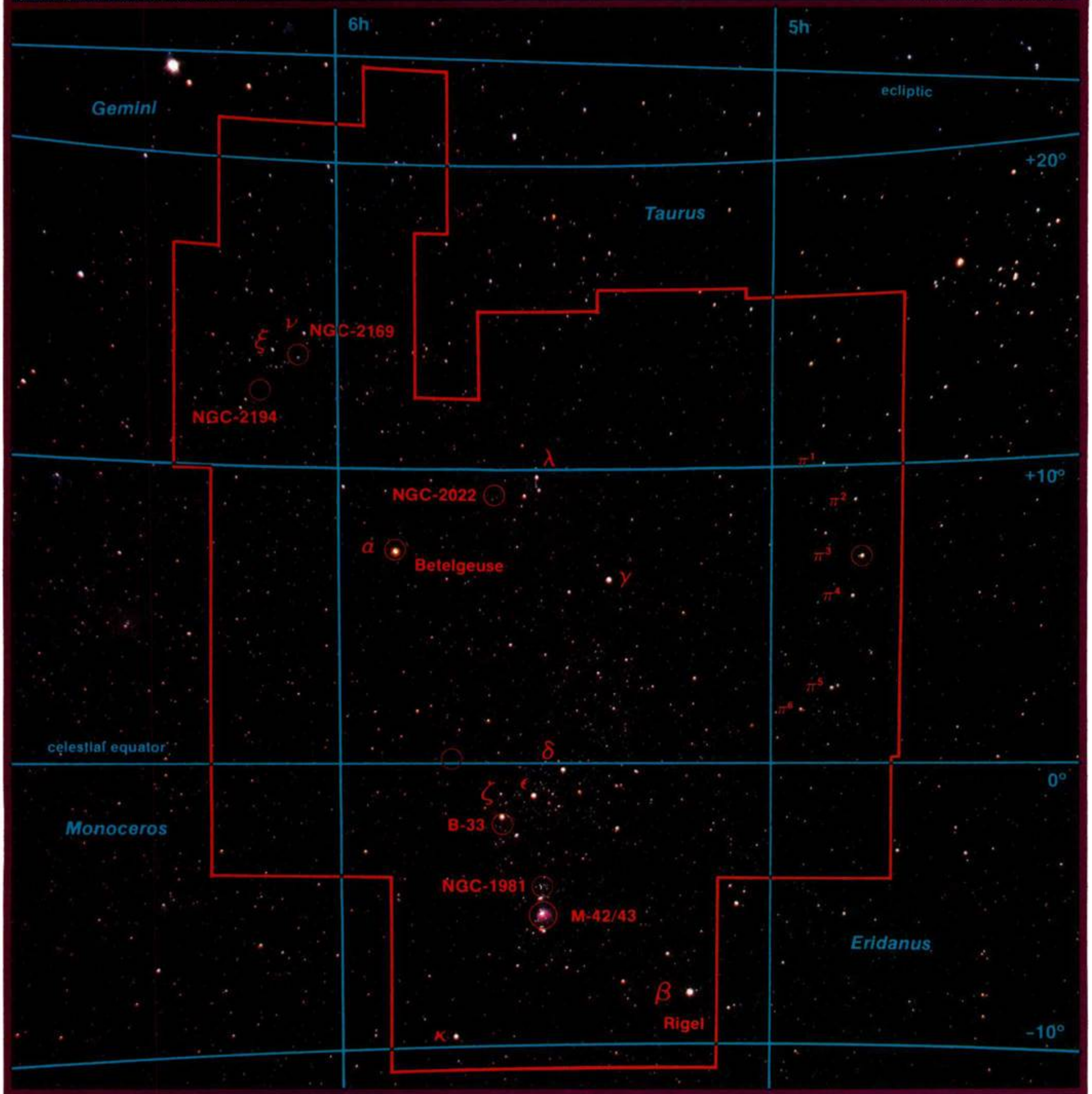
	Date	Altitude	Azimuth	Type & Extent of Elongation
Mercury	Feb. 8	6°	124°	West (morning sky) 26°
	Apr. 21	11°	288°	East (evening sky) 20°
	June 8	3°	73°	West (morning sky) 24°
	Aug. 19	1°	271°	East (evening sky) 27°
	Oct. 1	9°	90°	West (morning sky) 18°
	Dec. 13°	5°	231°	East (evening sky) 21°
Venus	June 16	24°	276°	East (evening sky) 45°
	Nov. 4	35°	120°	West (morning sky) 47°

The planets' altitudes and azimuths are given for 45 minutes after sunset (east elongations) of 45 minutes before sunrise (west elongations) as seen by an observer at 40° north latitude. In other latitudes the figures will vary slightly. North = azimuth 0° or 360°, east = 90°, south = 180°, and west = 270°.

photo by Brad Wallis & Robert Provin

orion

map by Robert Burnham


6h
5h
ecliptic
Gemini
+20°
Taurus
ν
NGC-2169
ξ
NGC-2194
λ
π¹
+10°
NGC-2022
π²
α
Betelgeuse
π³
γ
π⁴
π⁵
π⁶
celestial equator
δ
0°
ζ
ε
B-33
Monoceros
NGC-1981
M-42/43
Eridanus
β
Rigel
κ
-10°

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.	R.A. (2000)	Dec.
π^3	★	3.2	—	4h47m	+6°53′	4h50m	+6°58′
M-42	□	3.0	85′x60′	5h33m	-5°25′	5h35m	-5°23′
NGC-1981	○	8.0	18′	5h33m	-4°24′	5h35m	-4°22′
M-43	□	8.4	8′	5h33m	-5°18′	5h36m	-5°16′
B-33	—	—	2′	5h39m	-2°32′	5h41m	-2°31′
NGC-2022	■	13.0	25″	5h39m	+9°03′	5h42m	+9°04′
M-78	□	9.0	8′x6′	5h44m	+0°02′	5h47m	+0°03′
Betelgeuse (α)	∩★	0.4→1.3	5.7y	5h53m	+7°24′	5h55m	+7°24′
NGC-2169	○	7.0	4′	6h06m	+13°58′	6h09m	+13°57′
NGC-2194	○	10.5	8′	6h11m	+12°50′	6h14m	+12°49′

★	*Star*
★^{2}	*Double Star*
★^{3}	*Triple Star*
m★	*Regular Variable*
∩★	*Irregular Variable*
Ӿ★	*Eclipsing Variable*
○	*Open Cluster*
●	*Globular Cluster*
■	*Planetary Nebula*
□	*Bright Diffuse Nebula*
§0	*Elliptical Galaxy*
§S	*Spiral Galaxy*
§ʃ	*Barred Spiral Galaxy*
§#	*Peculiar/Irregular Galaxy*

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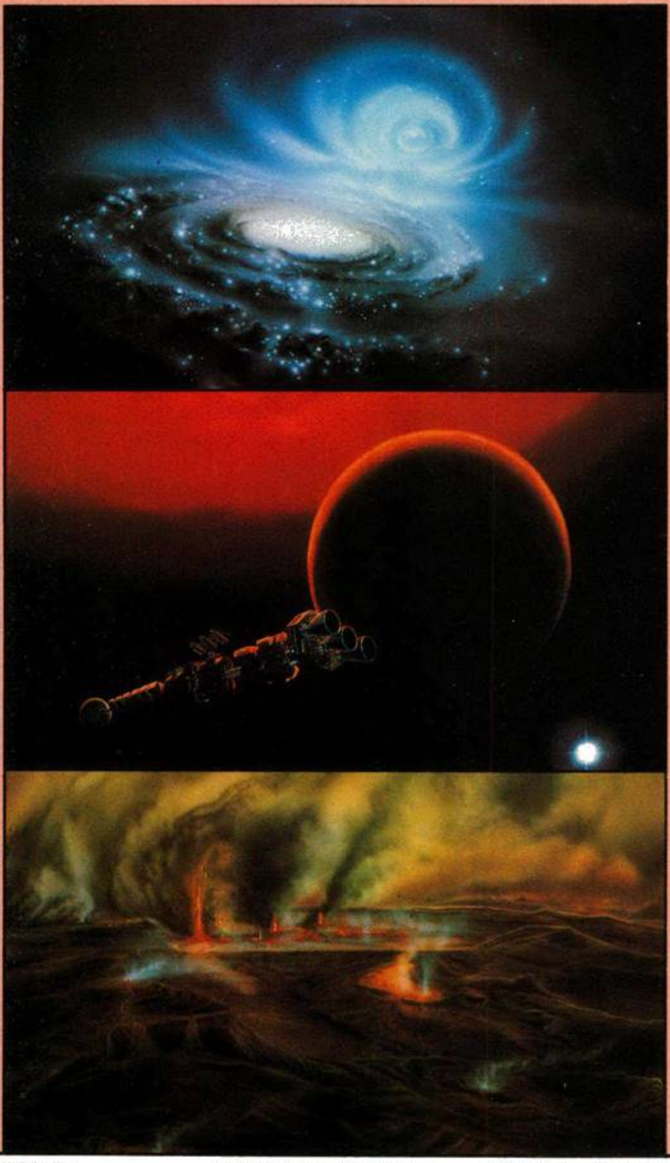

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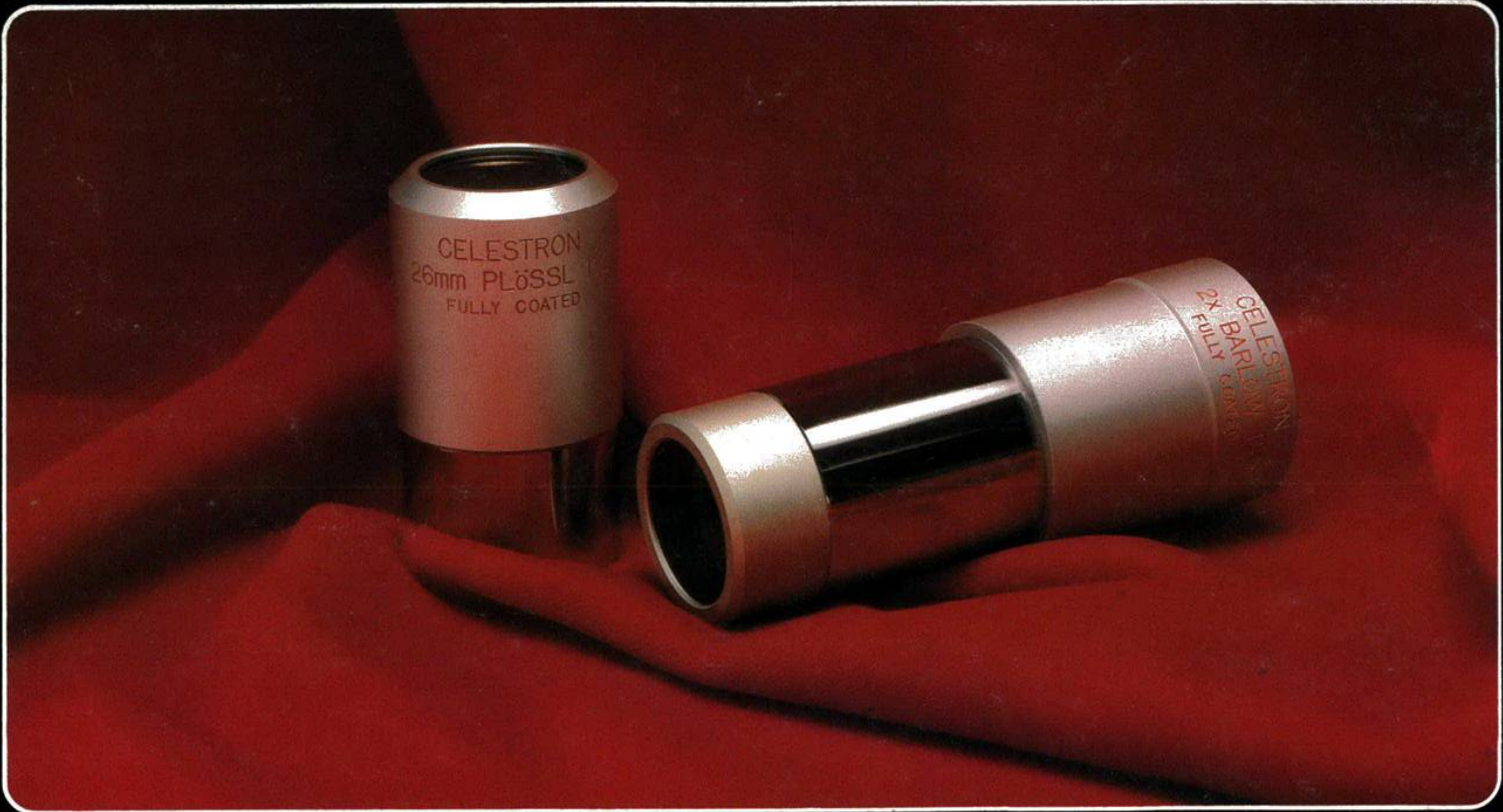
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